

***When Earth Songs Filled the Void of Space***



**A story about how science works and about real people...**

***When Earth Songs Filled the Void of Space***



**The time of the story runs from 1894 to 2001,  
but may include today...**

***When Earth Songs Filled the Void of Space***



Space [Merriam-Webster]: “the region beyond Earth’s atmosphere or beyond the solar system”  
Void [Merriam-Webster]: “containing nothing  
<void space>”

*When Earth Songs Filled the Void of Space*





So space or what we think about space is the topic

*When Earth Songs Filled the Void of Space*

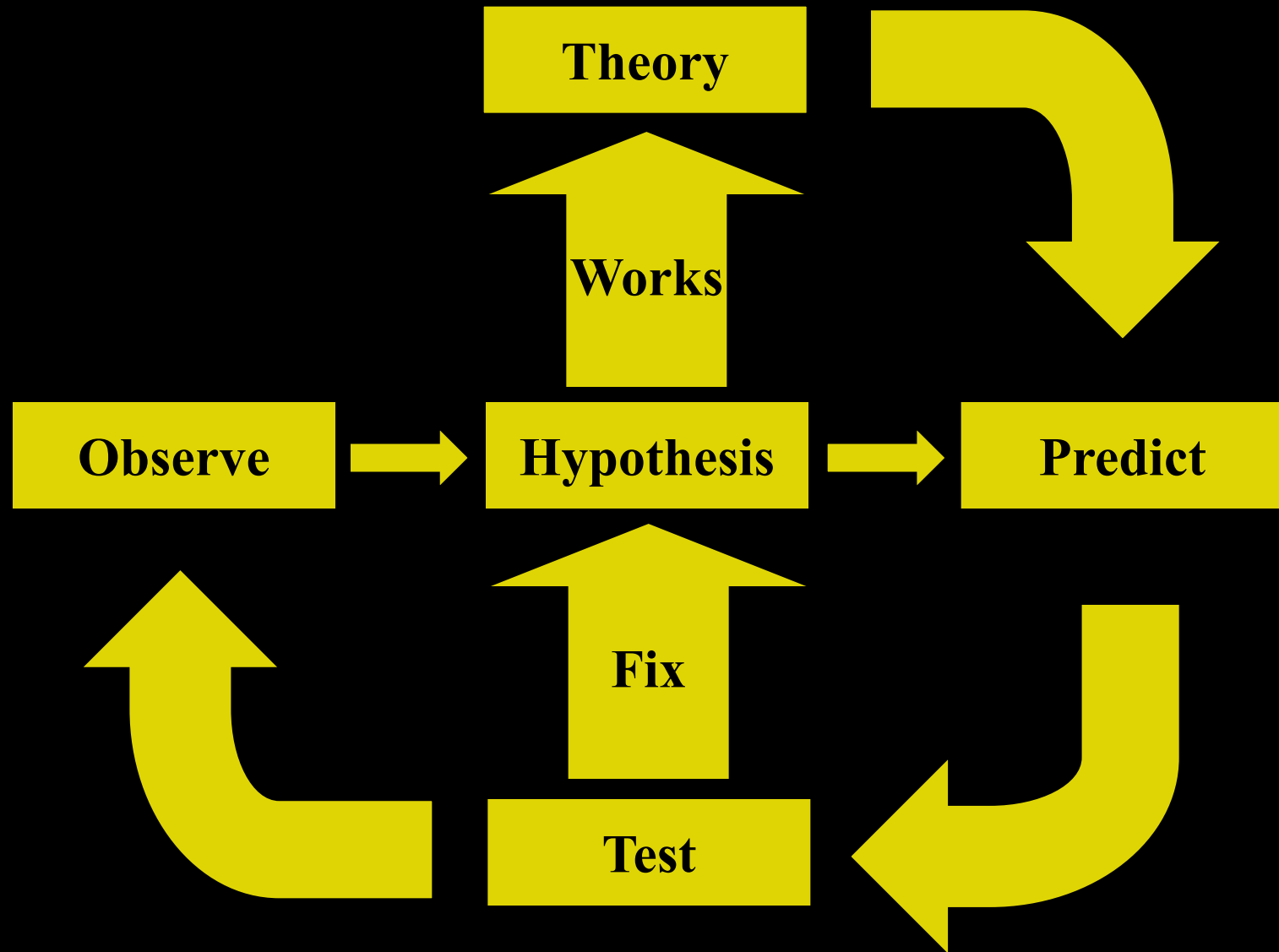




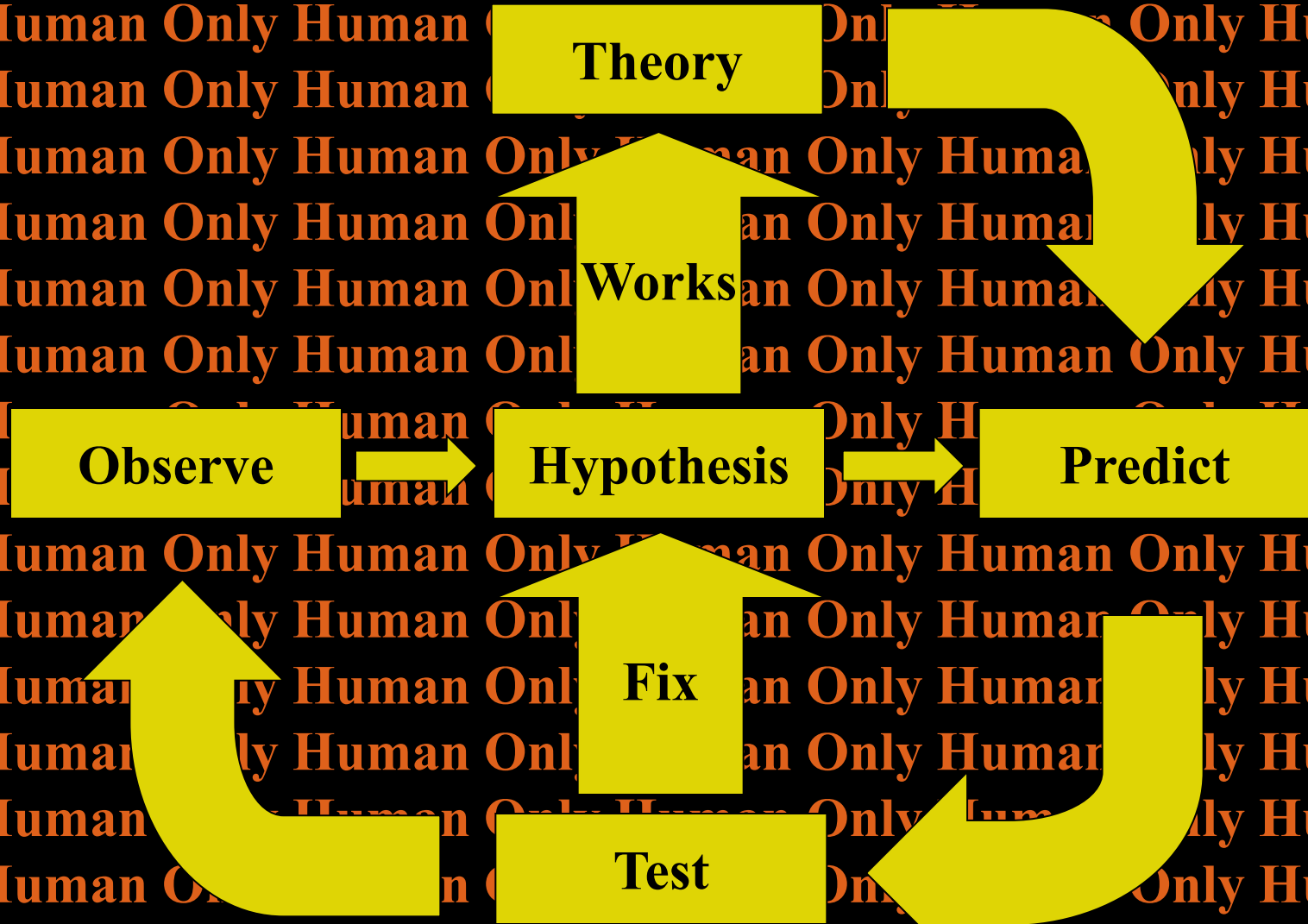
# James Randi

*“Science is best defined as a careful, disciplined, logical search for knowledge about any and all aspects of the universe, obtained by examination of the best available evidence and **always subject to correction and improvement upon discovery of better evidence. What's left is magic. And it doesn't work.**”*

# The Scientific Method



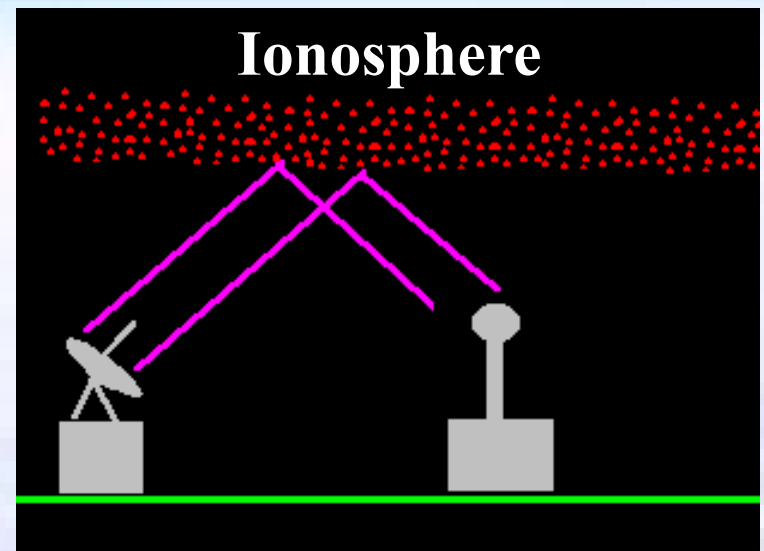
# The Scientific Method





**So Let's Observe a Little**















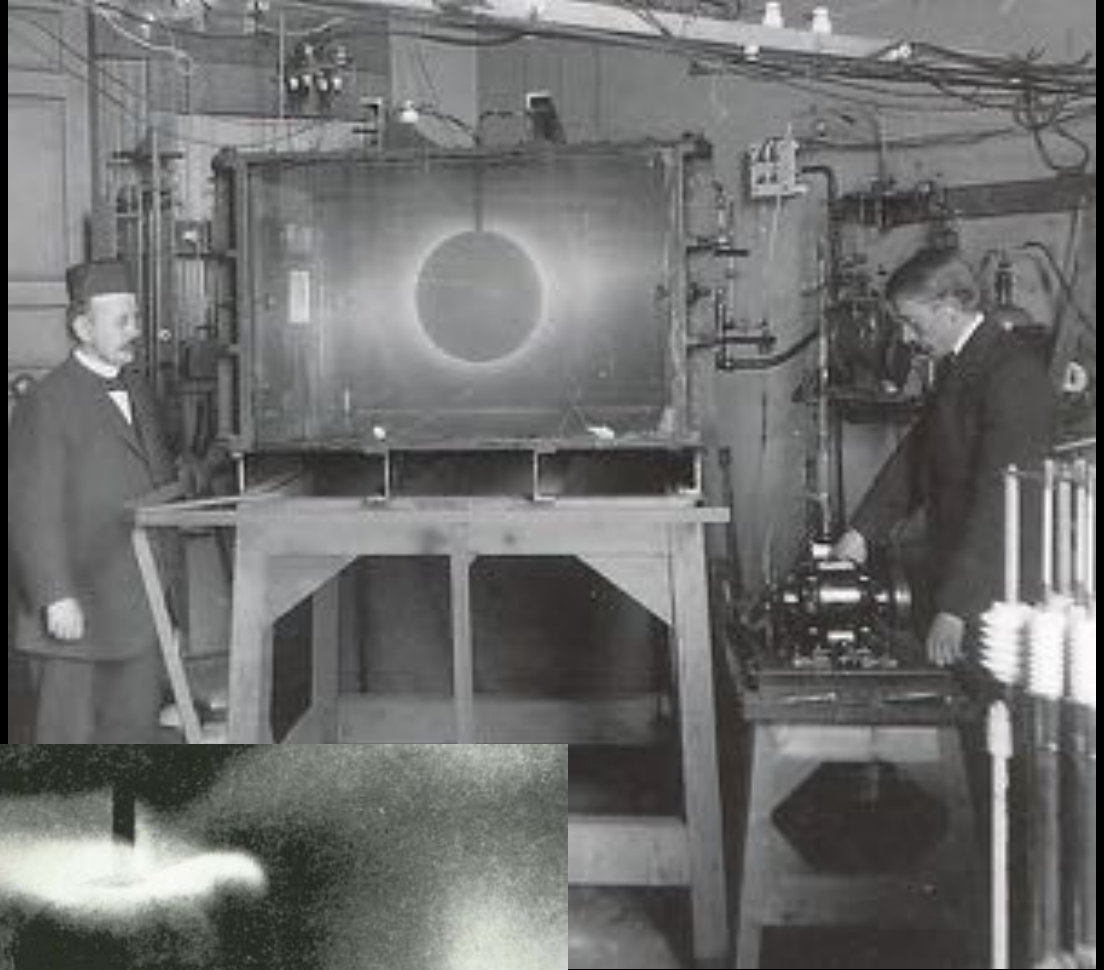
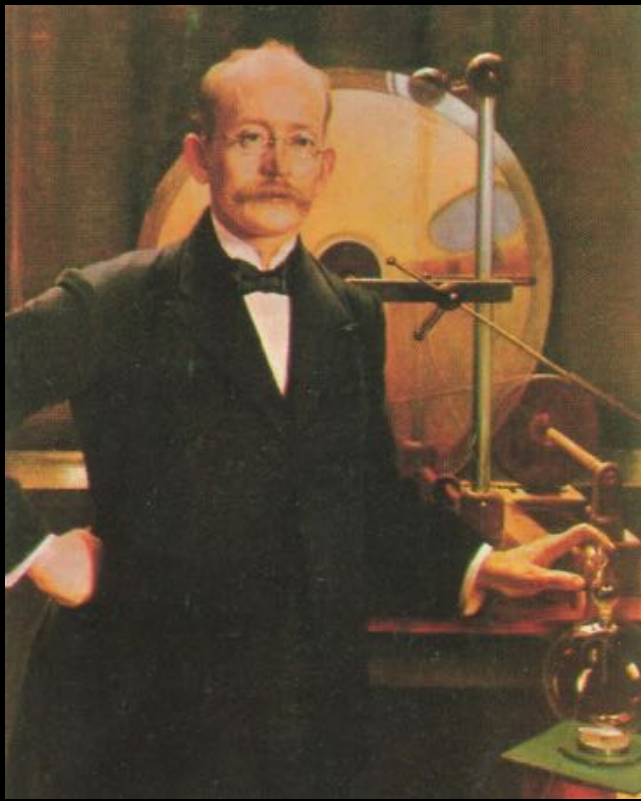












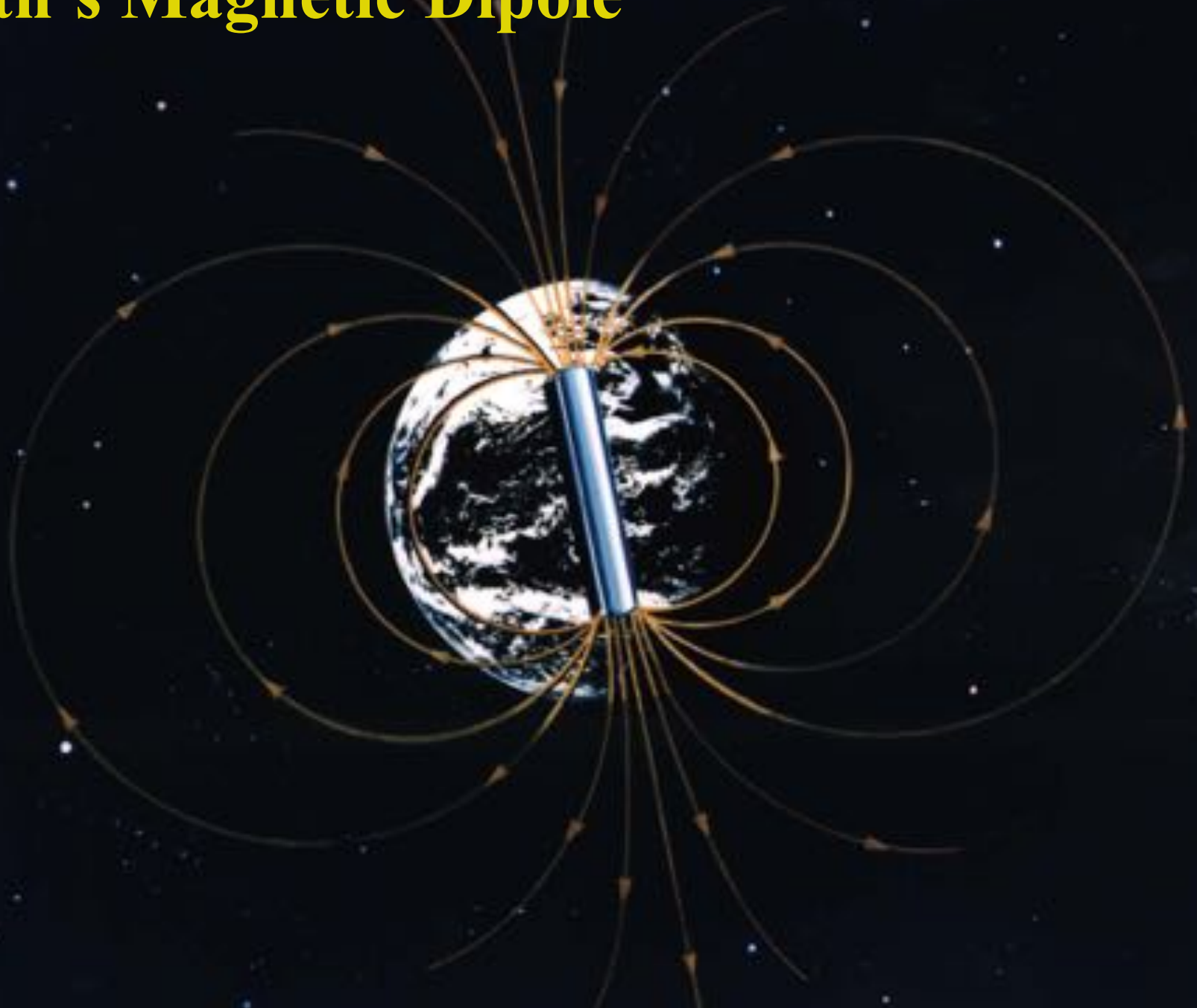
# Birkeland's

Terella  
Experiments in  
the 1890s

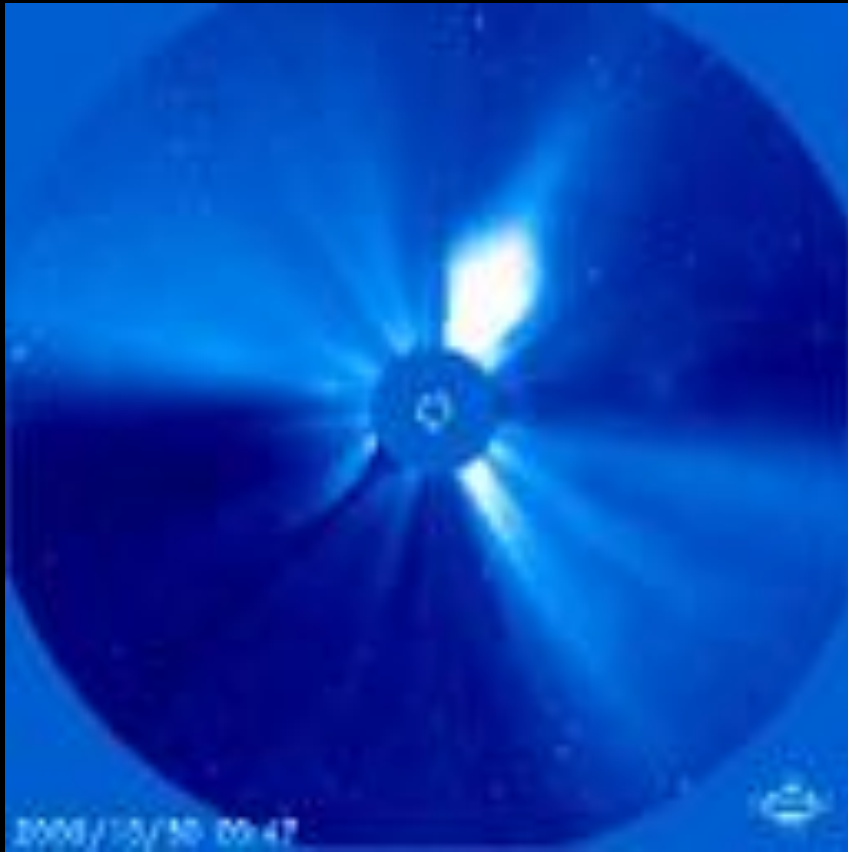




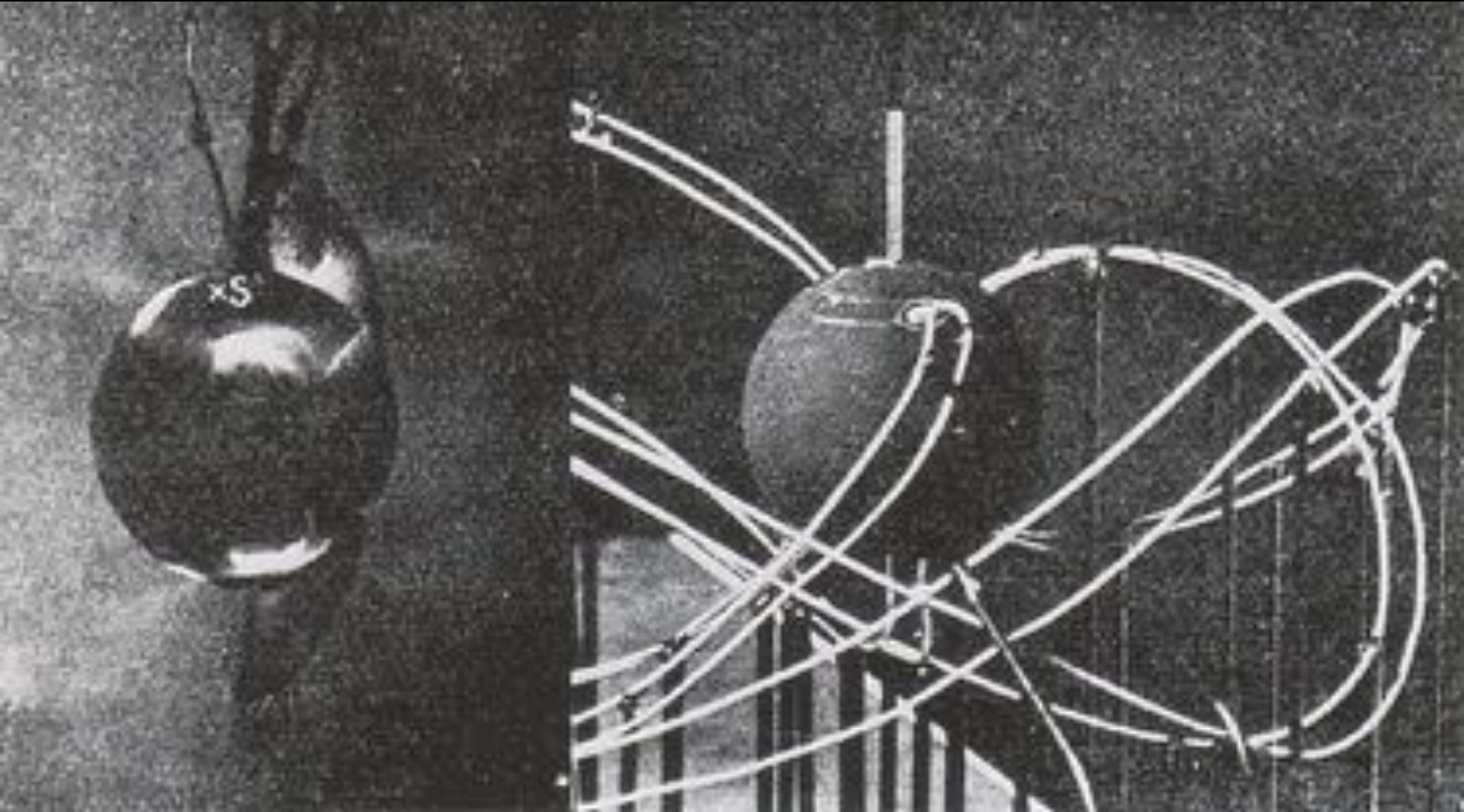
# Earth's Magnetic Dipole



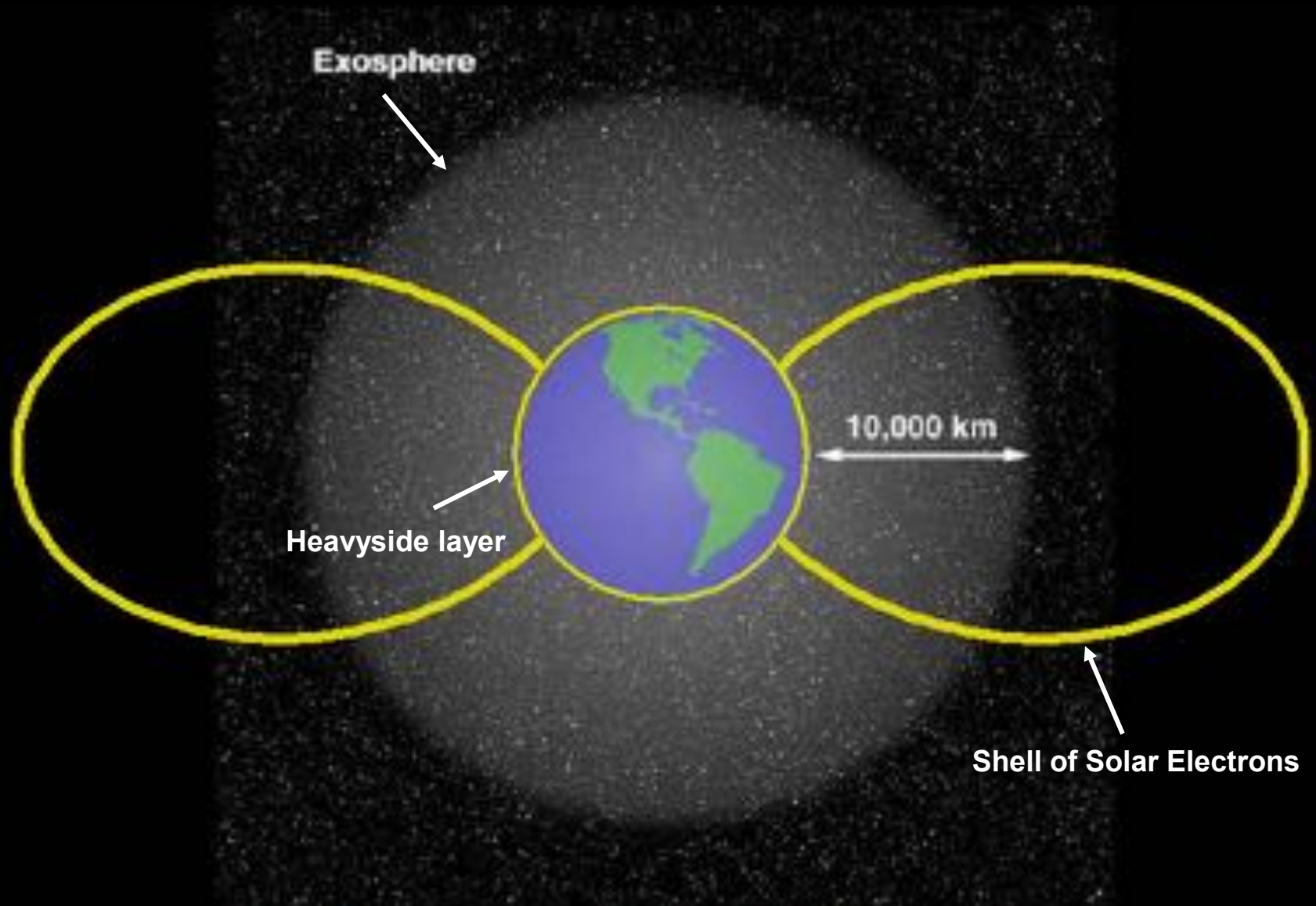
# **The Sun is a Copious Source of Plasma**



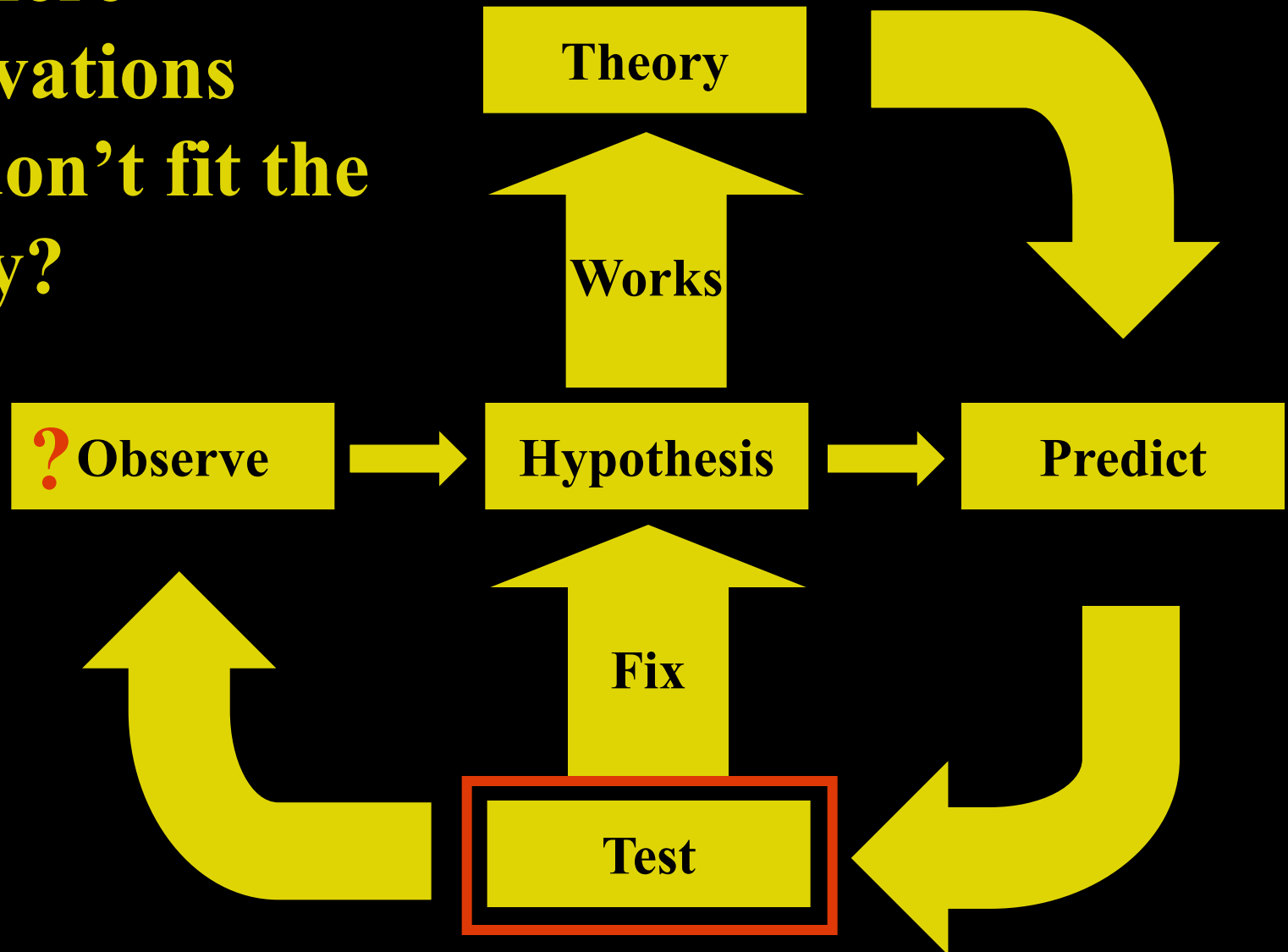
# A Shell of Solar Electrons is Formed by Earth's B-field



# The 1950 Picture of Space Near Earth

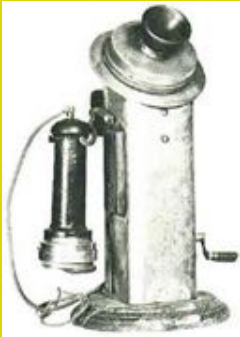


**So What's Next?**  
**Are there**  
**observations**  
**that don't fit the**  
**theory?**





# Legitimized Observations!



1894



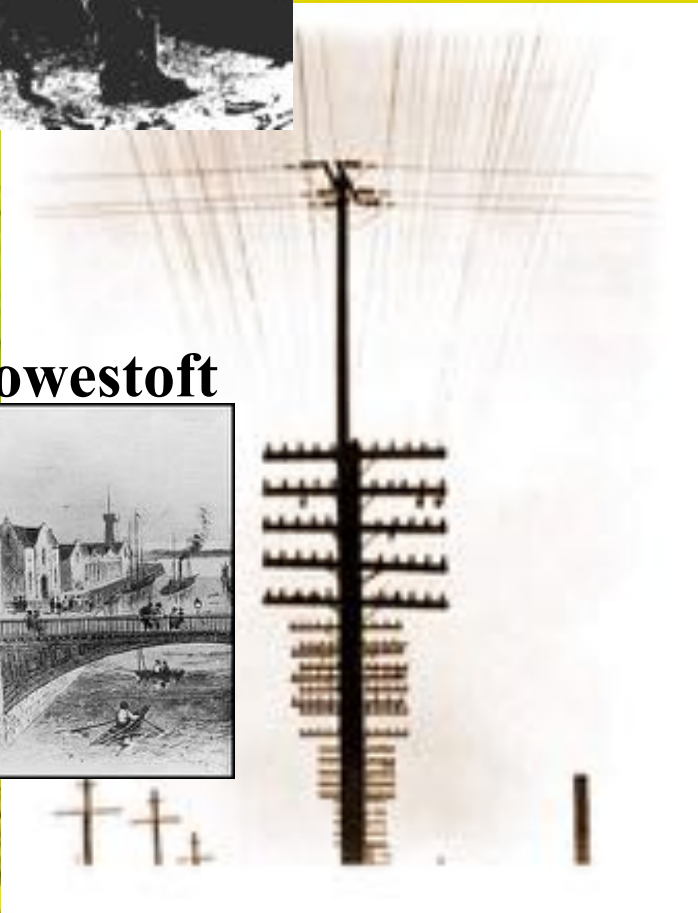
Llanfair



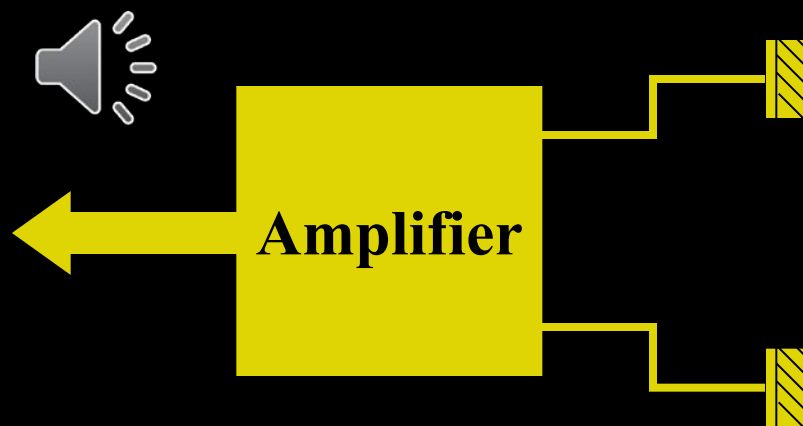
Haverfordwest



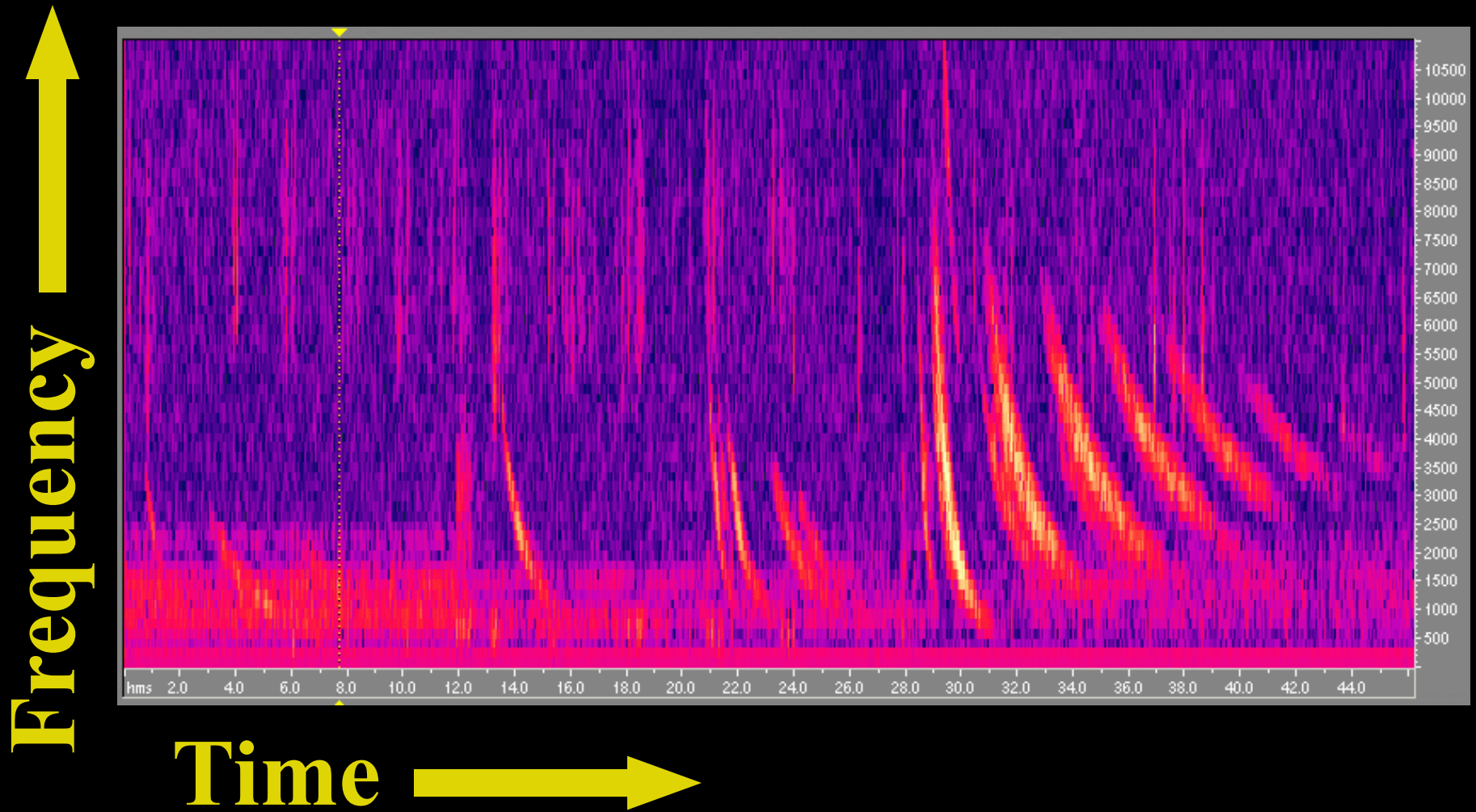
Lowestoft



# World War I



# Burton and Boardman Introduced the Sound Spectrograph in 1930

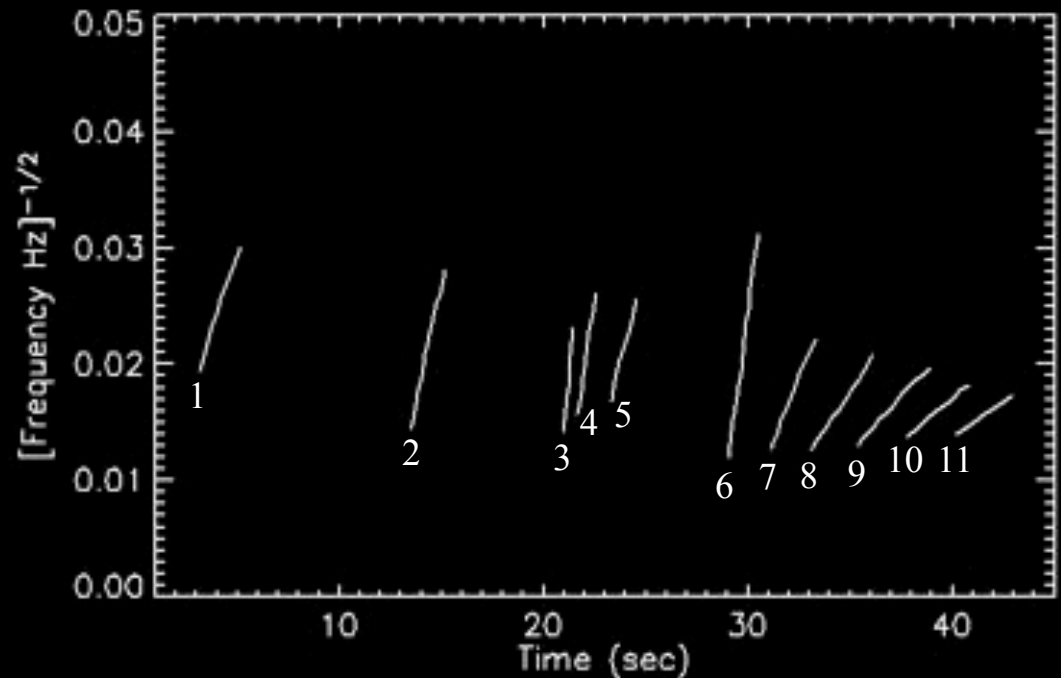
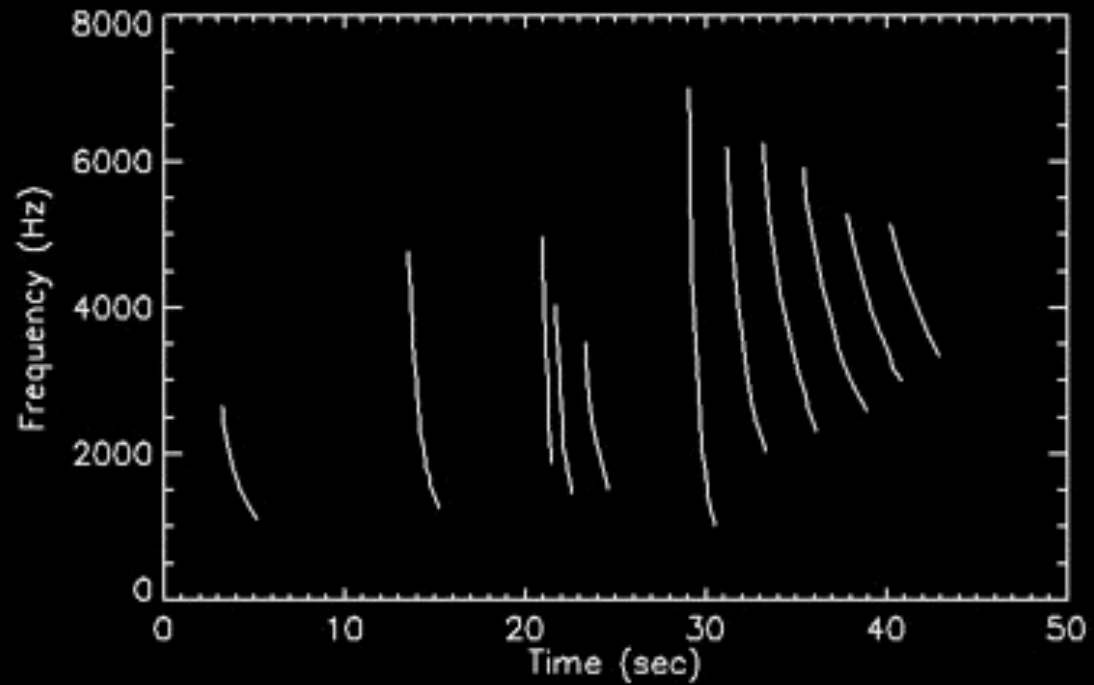




# Frequency Dispersion

$$f^{-1/2} = t/D$$

Trace	D	T <sub>0</sub>
1	186	-0.5
2	117	11.8
3	53	20.2
4	83	20.4
5	150	20.7
6	75	28.2
7	228	28.2
8	377	28.3
9	532	28.4
10	675	28.5
11	808	28.9





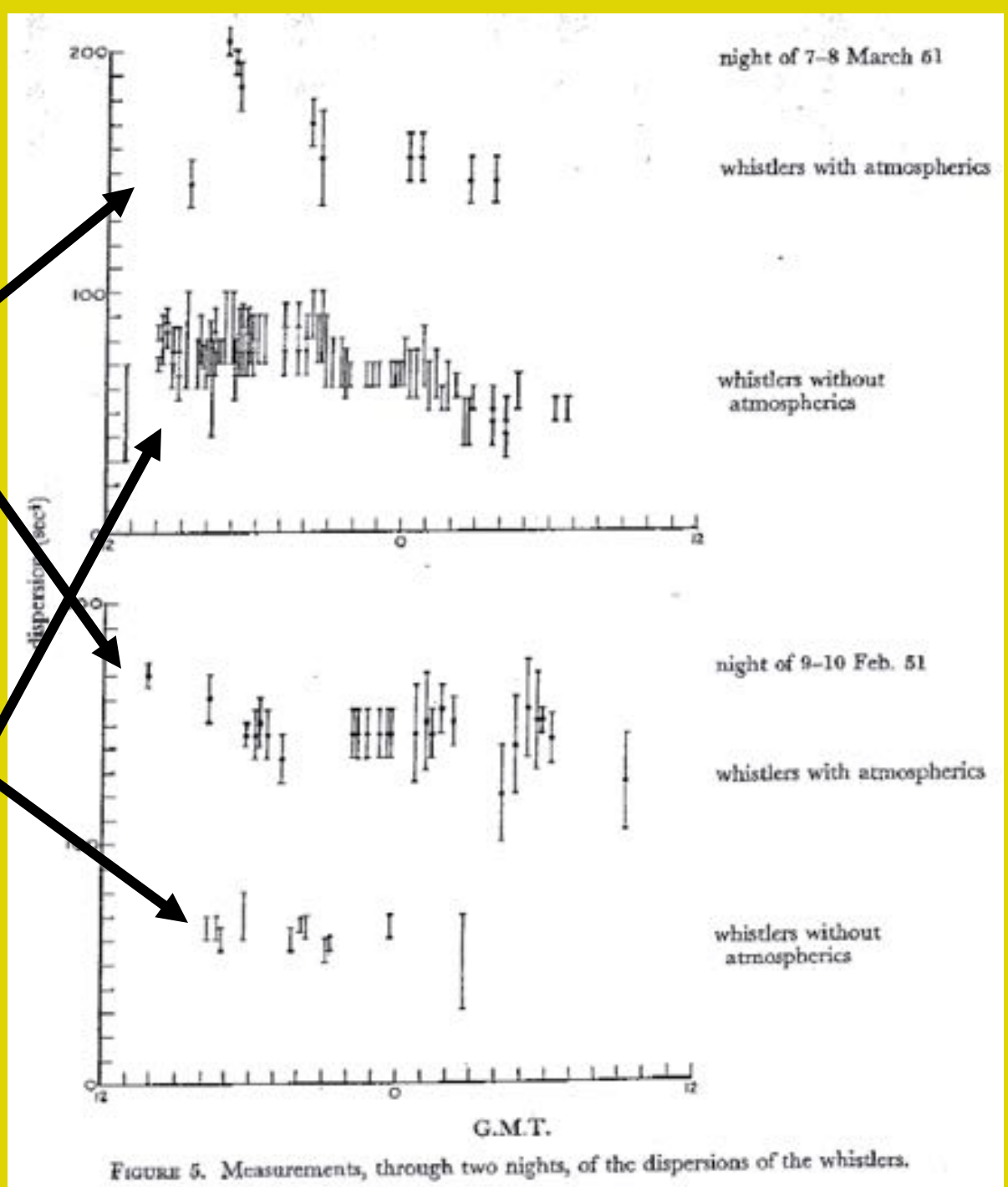
**1952**  
**L. R. Owen Storey**  
**Cavendish Laboratory**  
**University of Cambridge**





**Whistlers with  
Atmospherics**

**Whistlers without  
Atmospherics**



## Multiple-flash

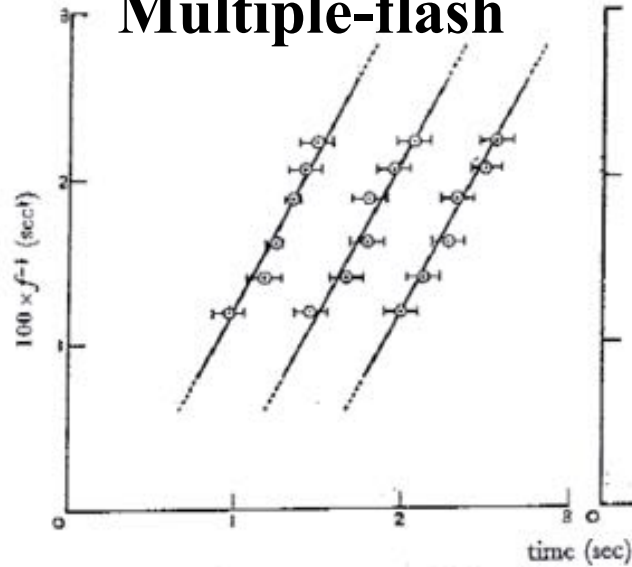


FIGURE 8. Multiple-flash type group of short whistlers.

## Whistler pairs

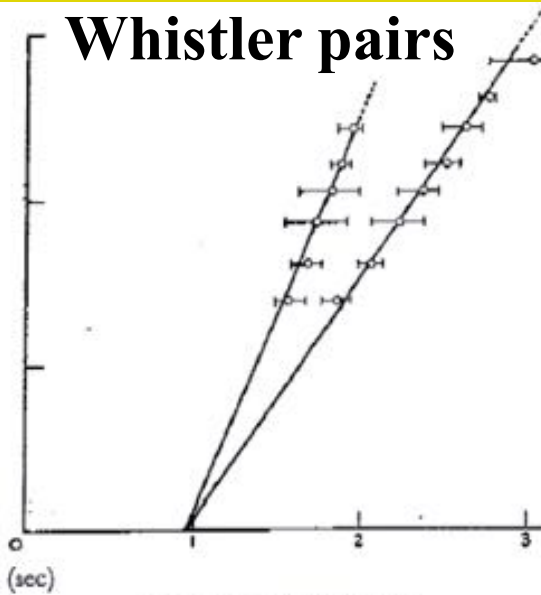


FIGURE 9. Whistler pair.

## Triple-D

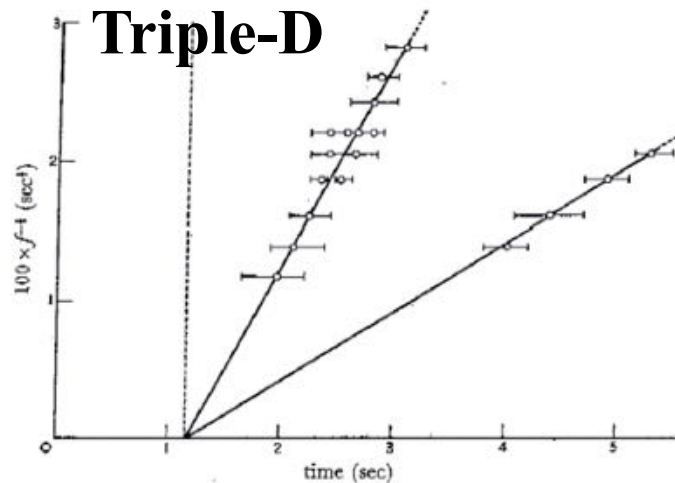


FIGURE 6. Short whistler with triply dispersed 'echo'.

## Overlapping

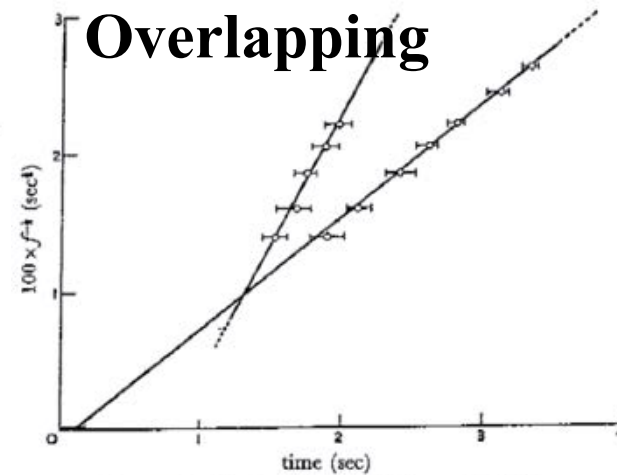
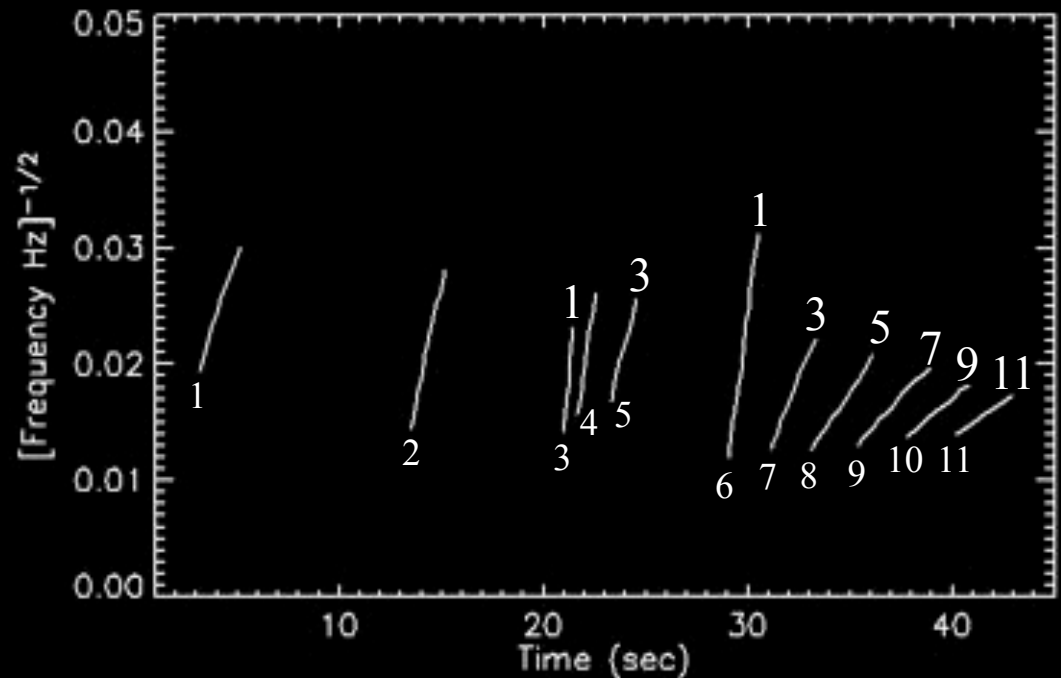
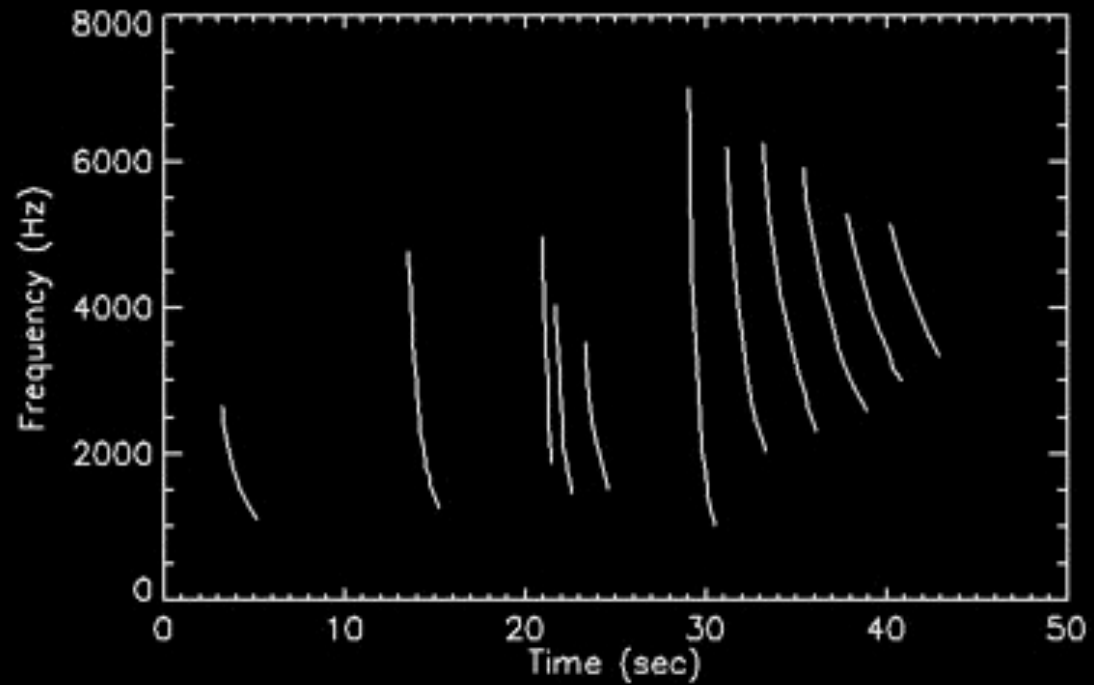


FIGURE 4. Short and long whistler overlapping.

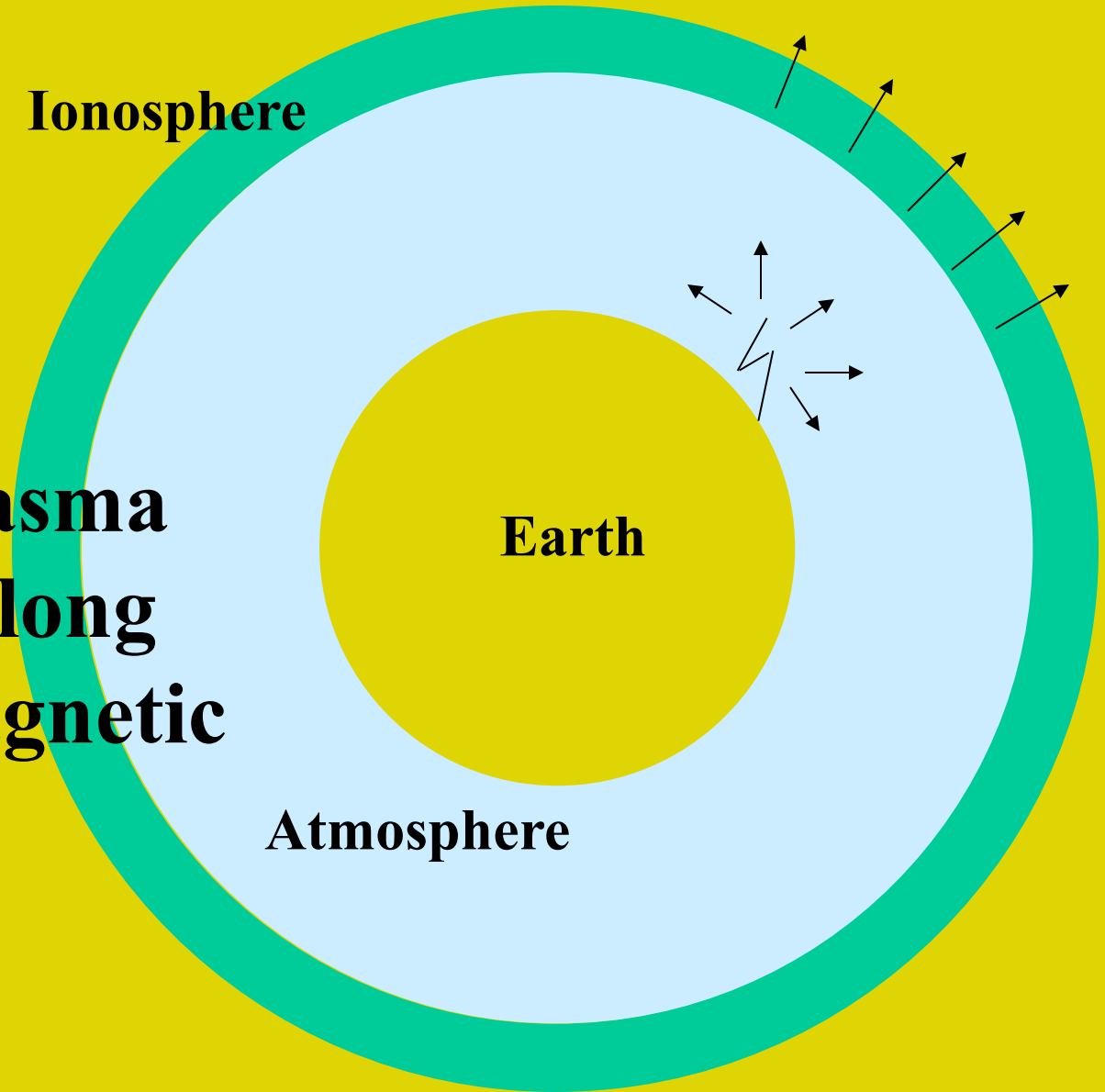
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7	228	28.2
8	377	28.3
9	532	28.4
10	675	28.5
11	808	28.9



**Dispersive &  
anisotropic  
ionospheric plasma  
guides waves along  
the Earth's magnetic  
field**



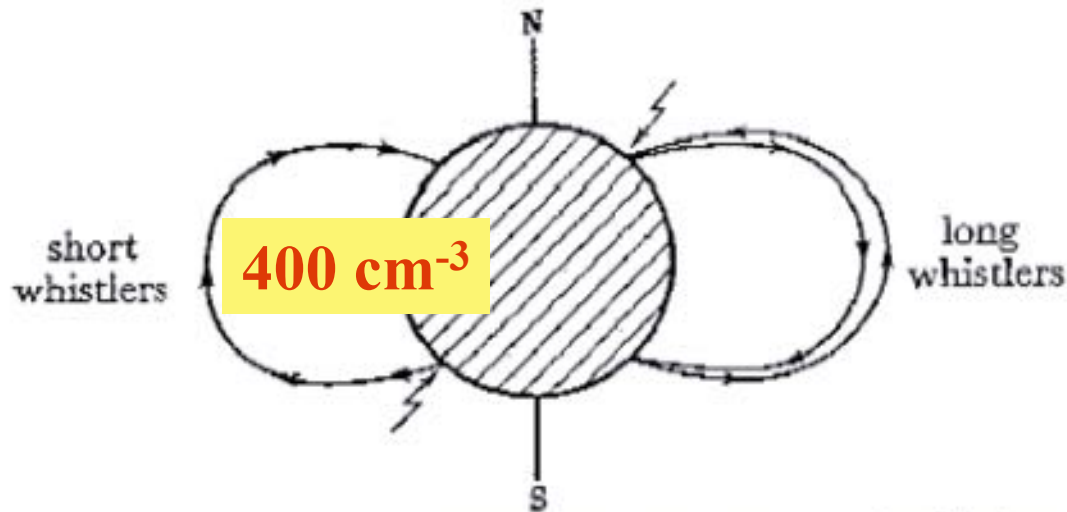


FIGURE 16. Suggested paths of the two types of whistler.

## **BUT THERE IS A PROBLEM !**

**Ionosphere can typically only produce  $D \sim 2 \text{ s}^{1/2}$   
while dispersions of  $D \sim 60 \text{ s}^{1/2}$  are measured.**

**WORSE: H. J. A. Ratcliffe, Owen's thesis adviser, presents his results at the 1952 URSI meeting in Sydney, but notes Owen's theoretical interpretation is probably wrong.**



**mid – 1950's**

**Robert Helliwell**

**Seattle, WA**

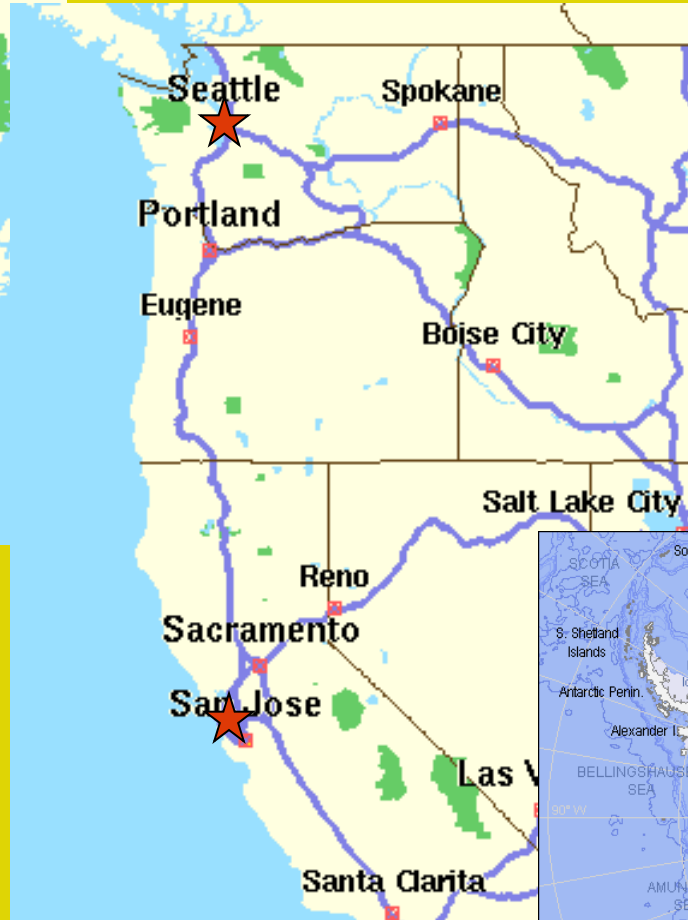


**“The Father of  
Whistler Research”**



**Unalaska, AK**

**Stanford, CA**



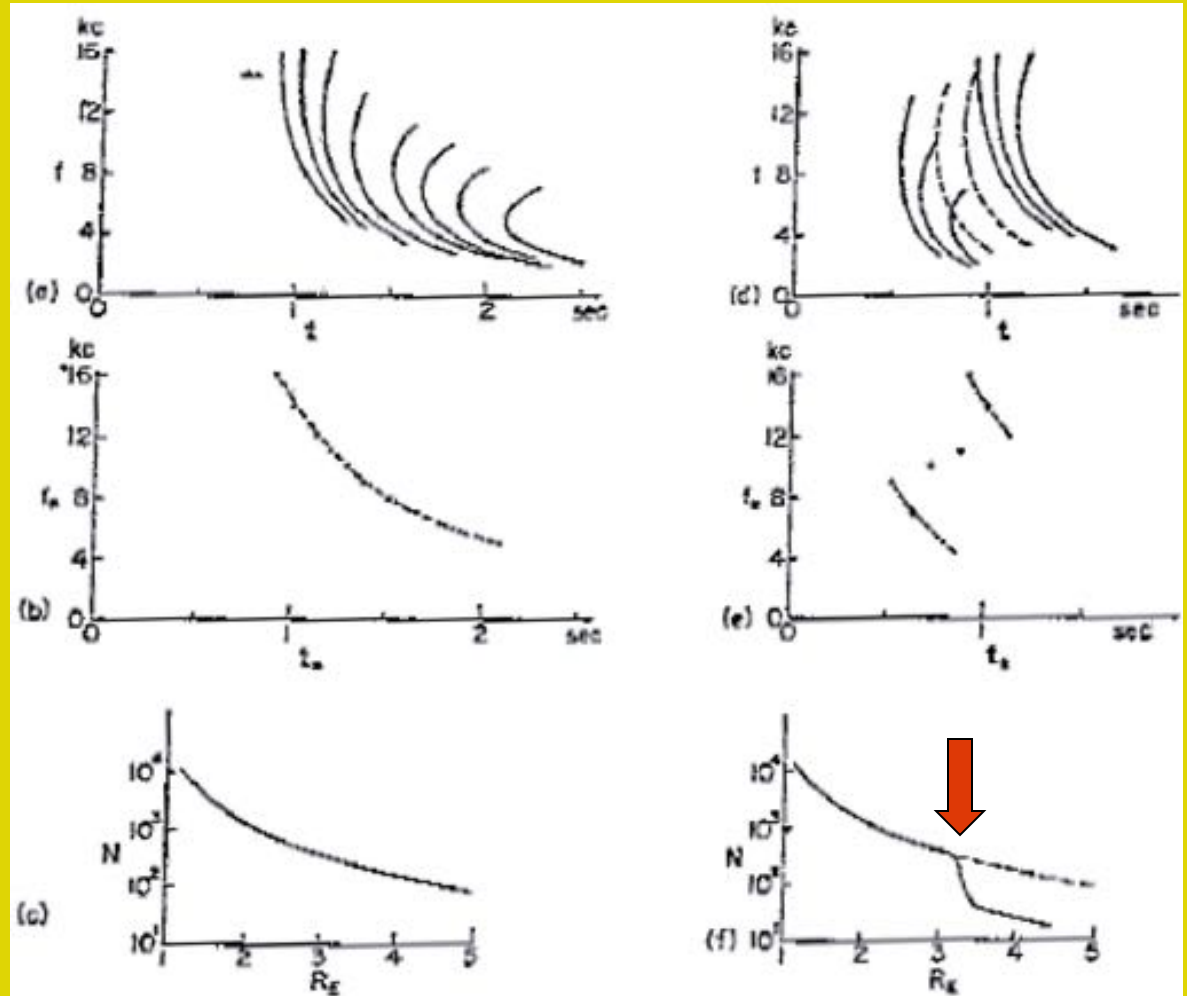
**Byrd Station,  
Antarctica**





# Donald Carpenter, 1963

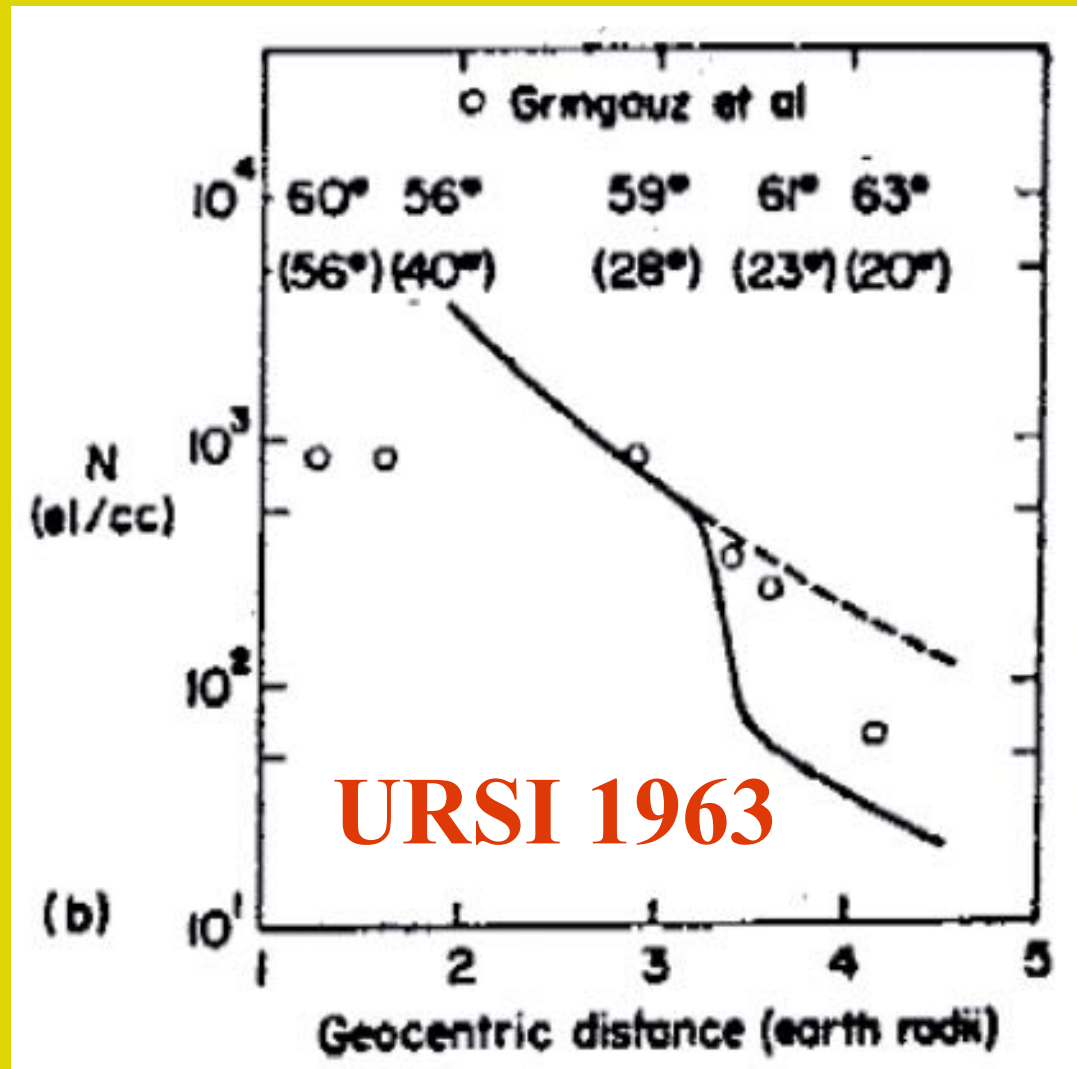
Discovers the  
Plasmapause  
from ground  
whistlers





# Konstantin Gringauz, 1959

Makes the  
first in-space  
measurements  
of the  
plasmasphere  
from Luna 2



# Schumann Resonances



Extremely low frequencies (ELF) around 7.83 (fundamental), 14.3, 20.8, 27.3 and **33.8** Hz

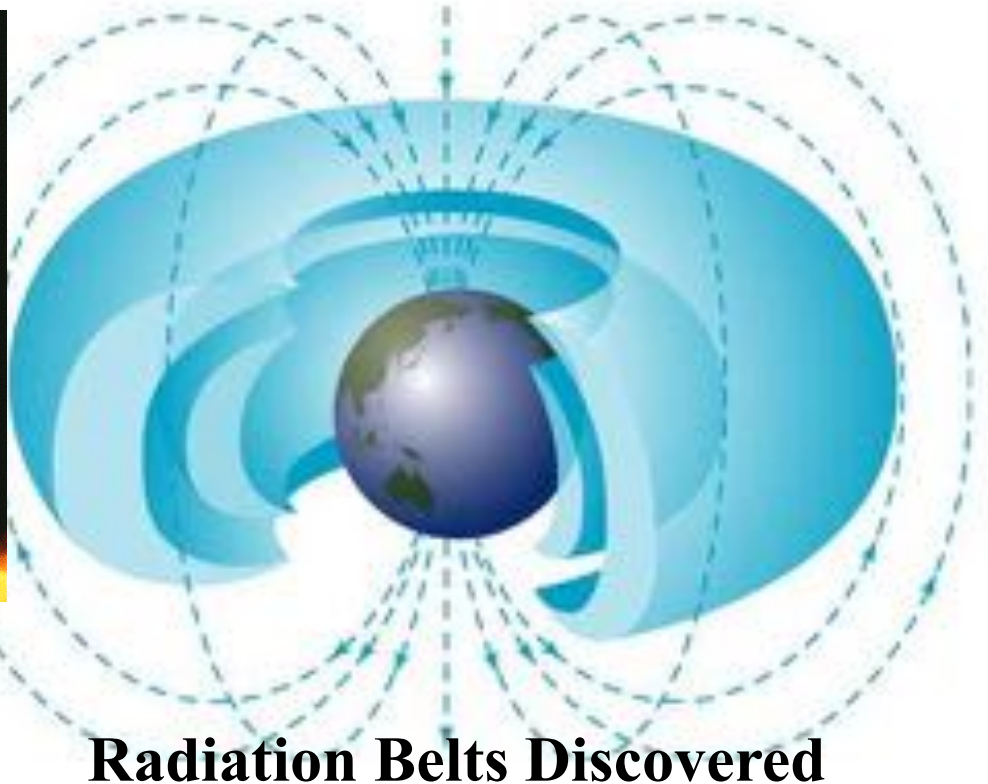
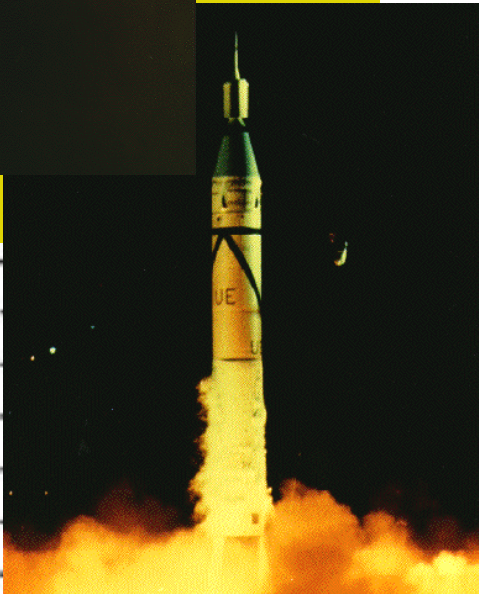
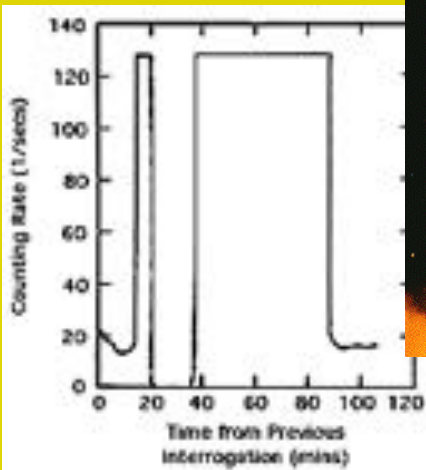
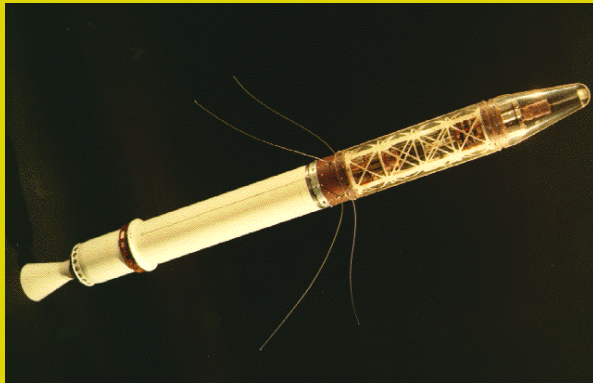




Animation of ELF wave propagation

# Explorer 1

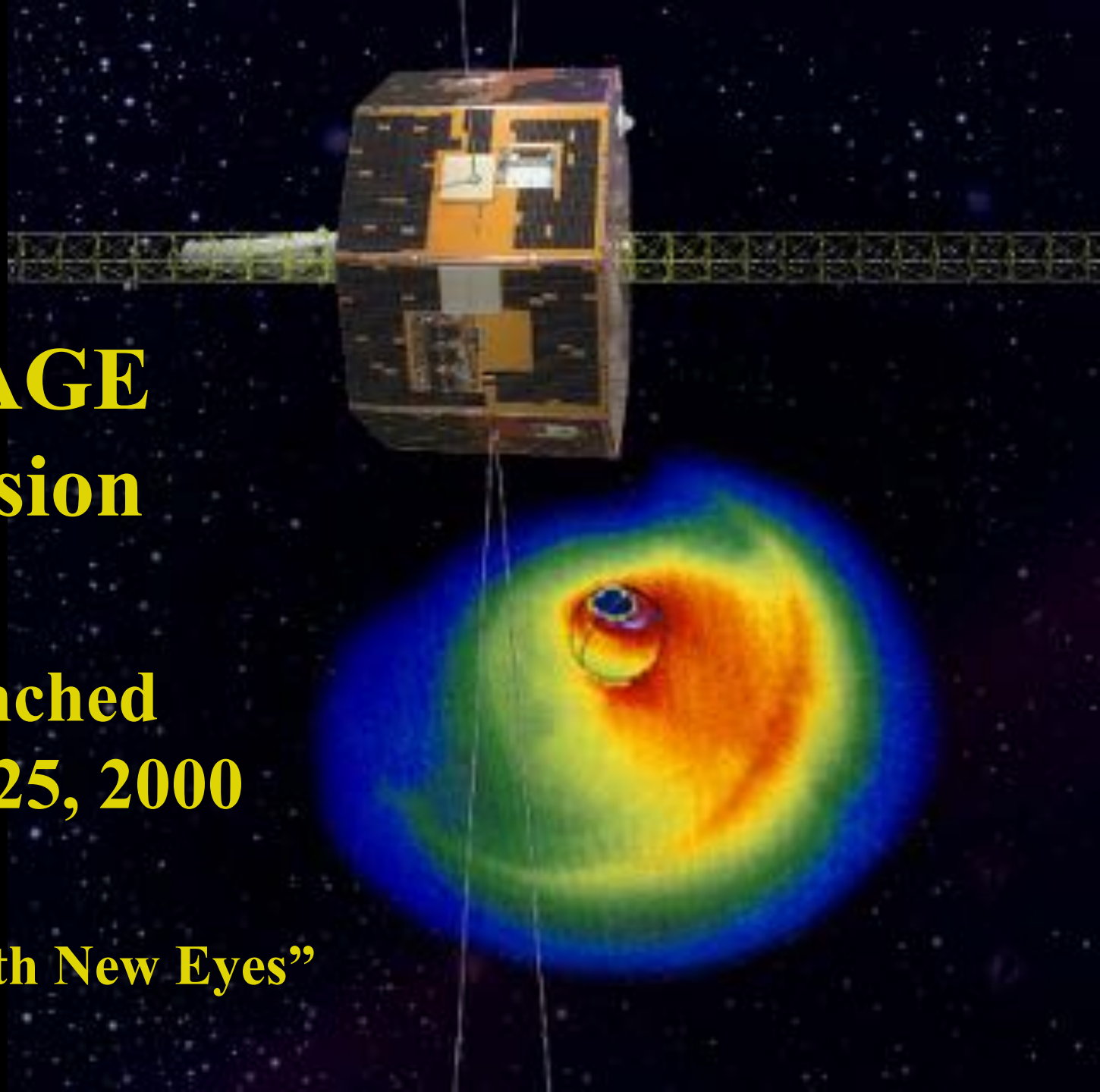
## January 31, 1958



# **IMAGE Mission**

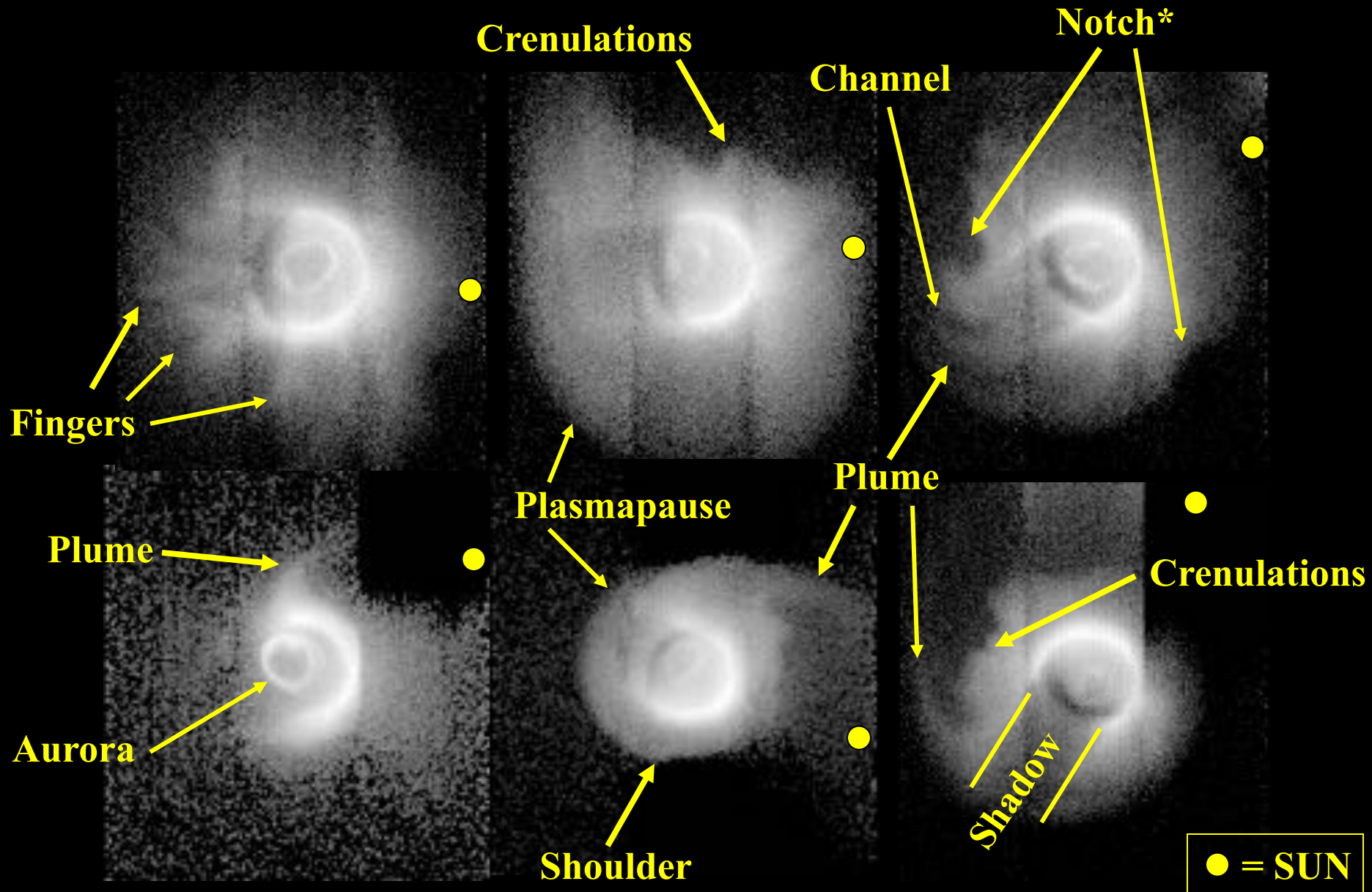
**Launched  
March 25, 2000**

**“Seeing With New Eyes”**



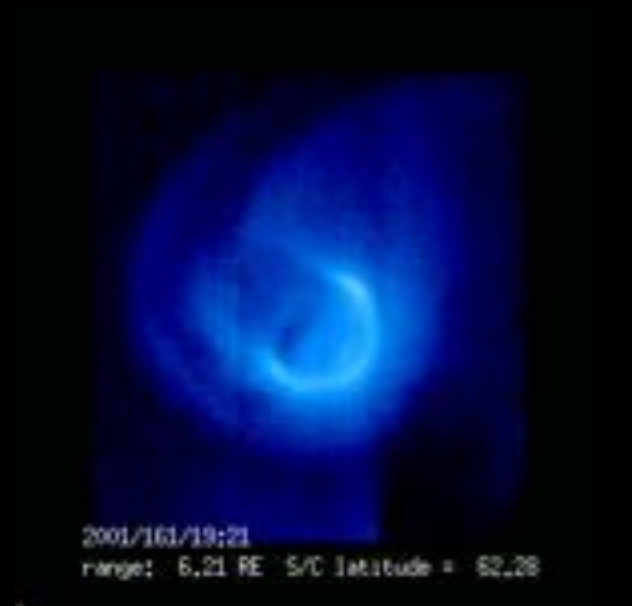
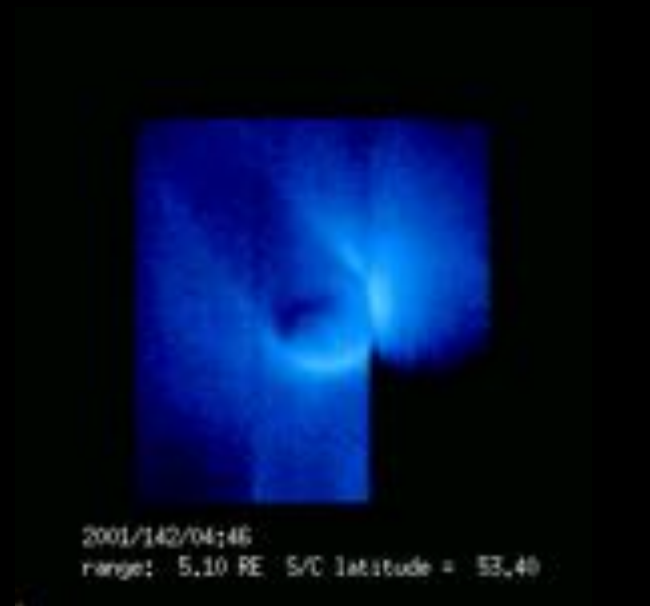
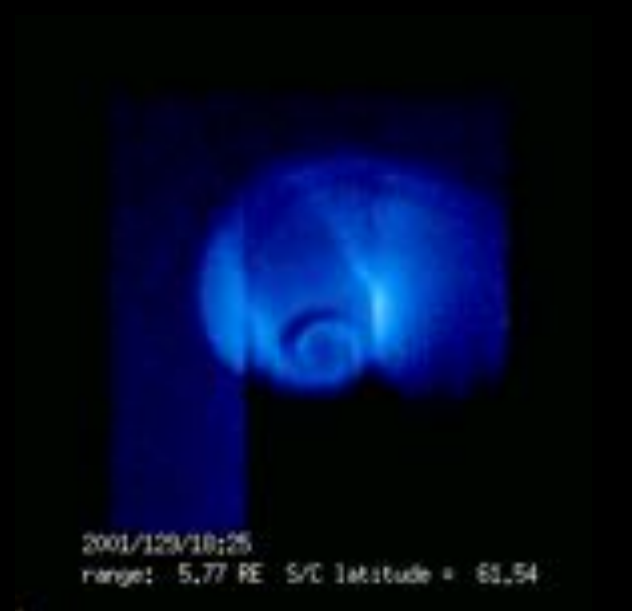
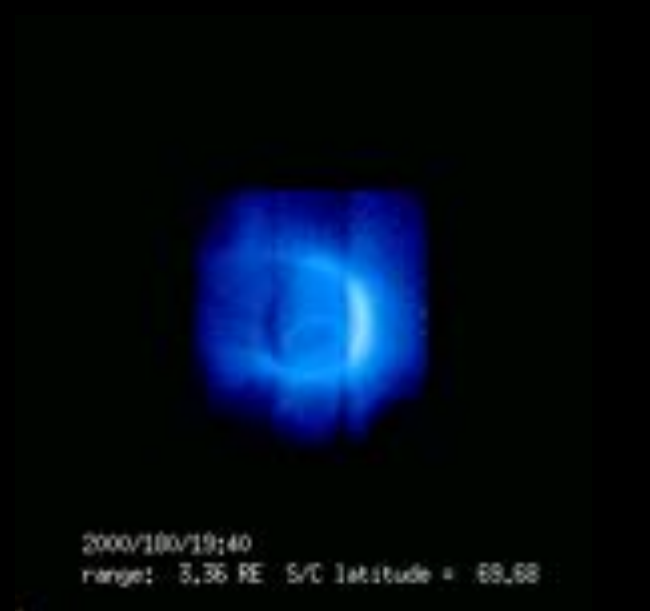


# The Plasmasphere We can See!

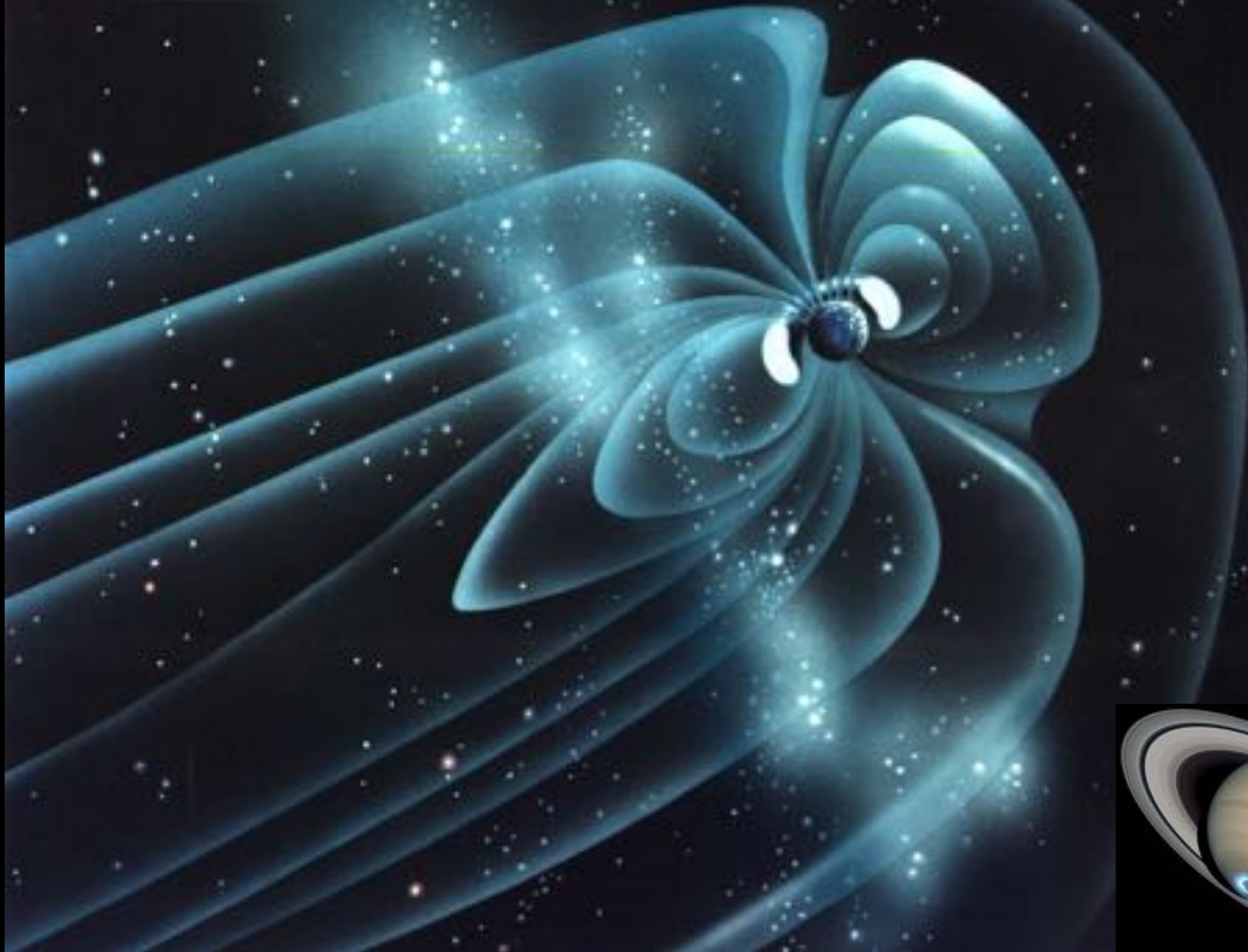




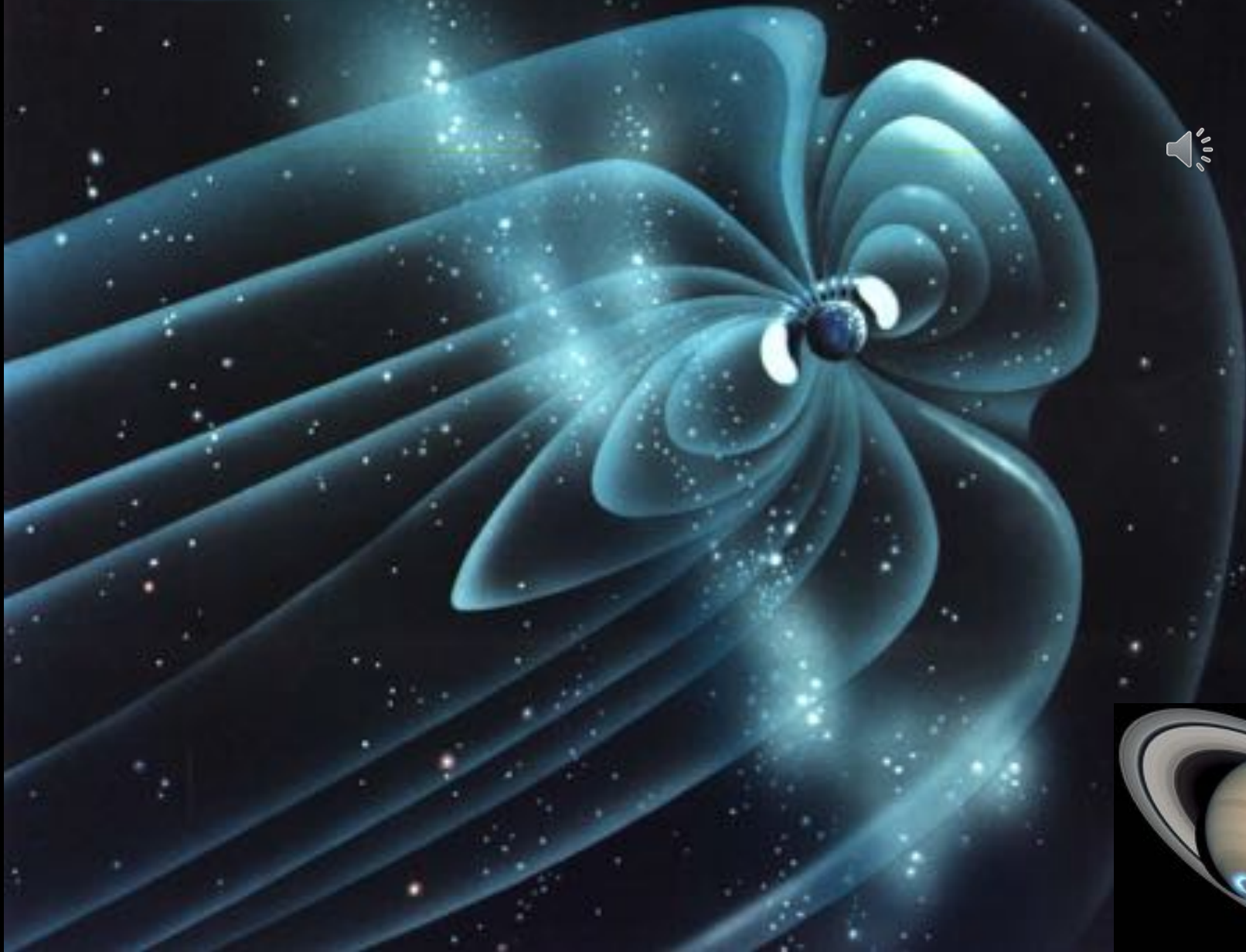
# The Plasmasphere is reborn with our new eyes.



# Upstream of Bow Shock

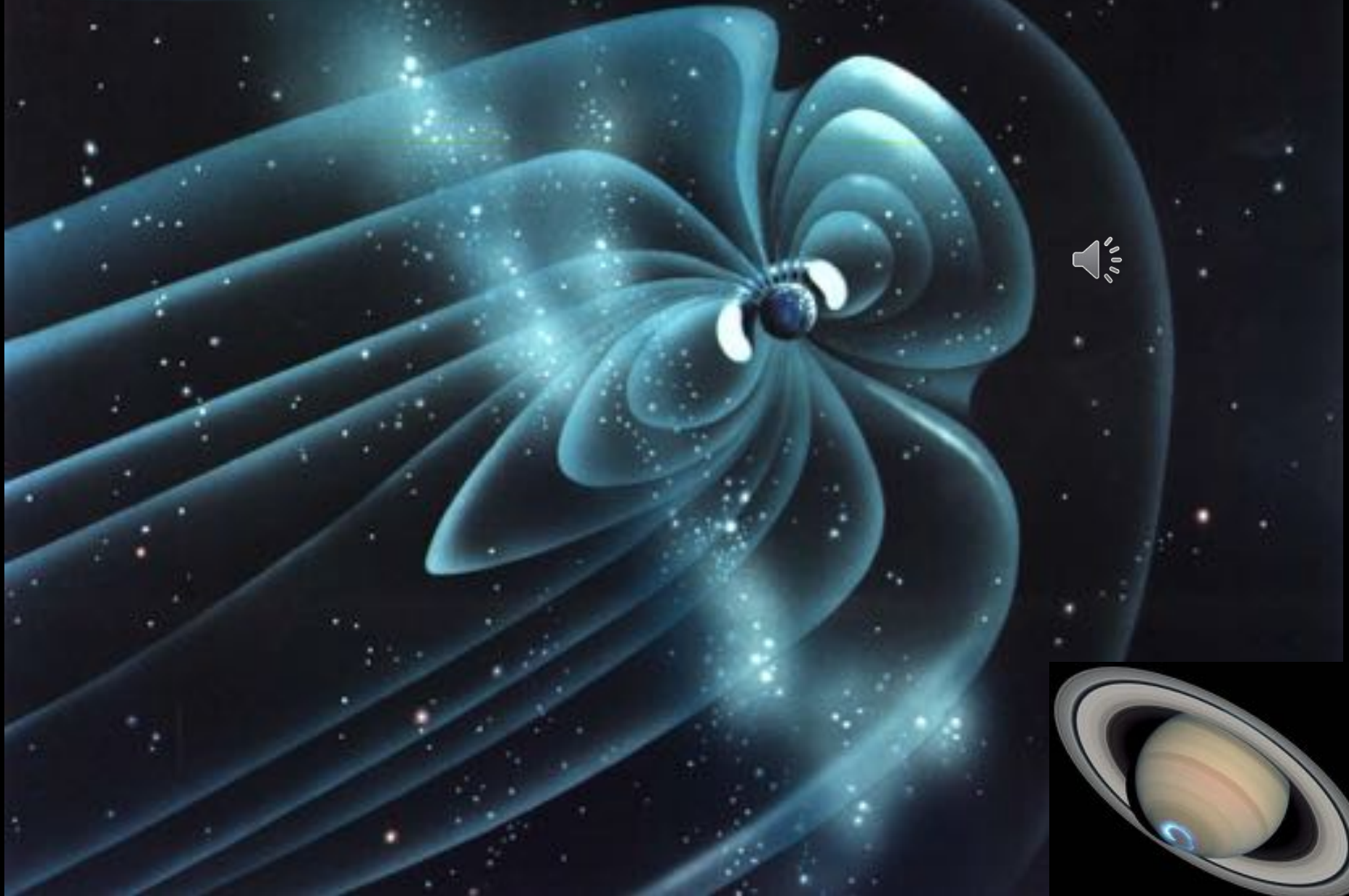


# Bow Shock-Magnetosheath



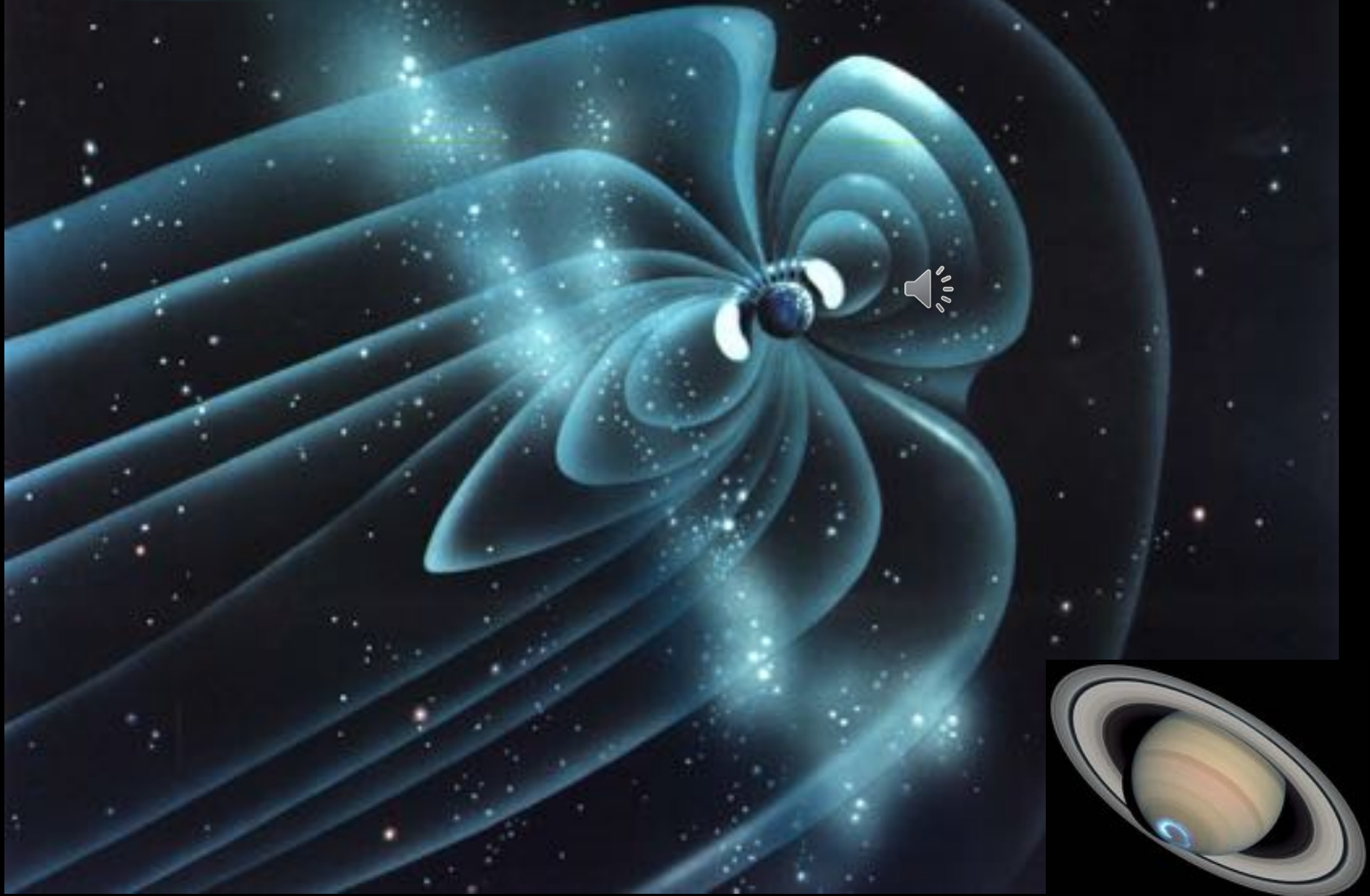


# Lion Roars - Magnetosheath

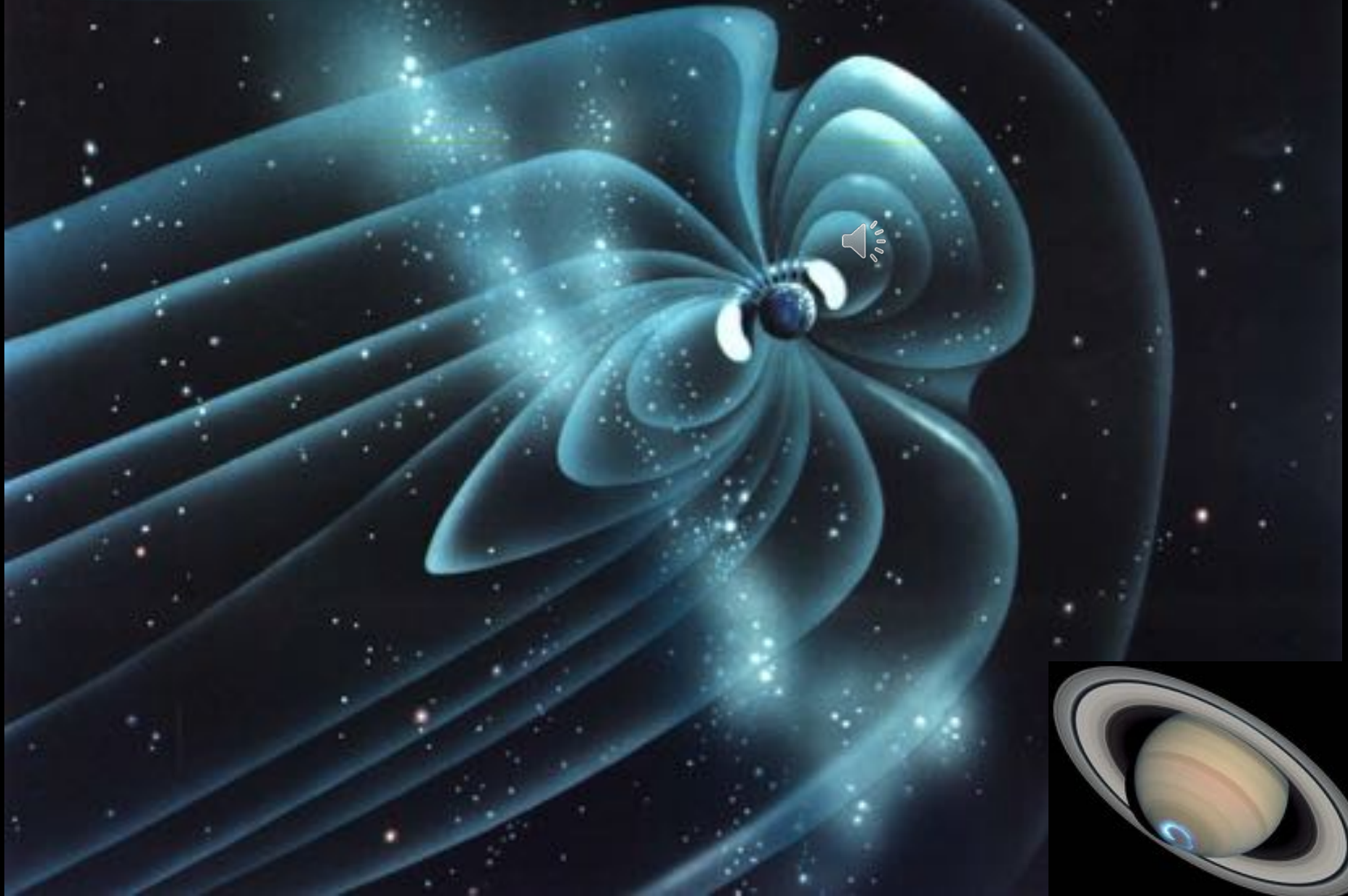




# Magnetospheric Upper Hybrid Noise

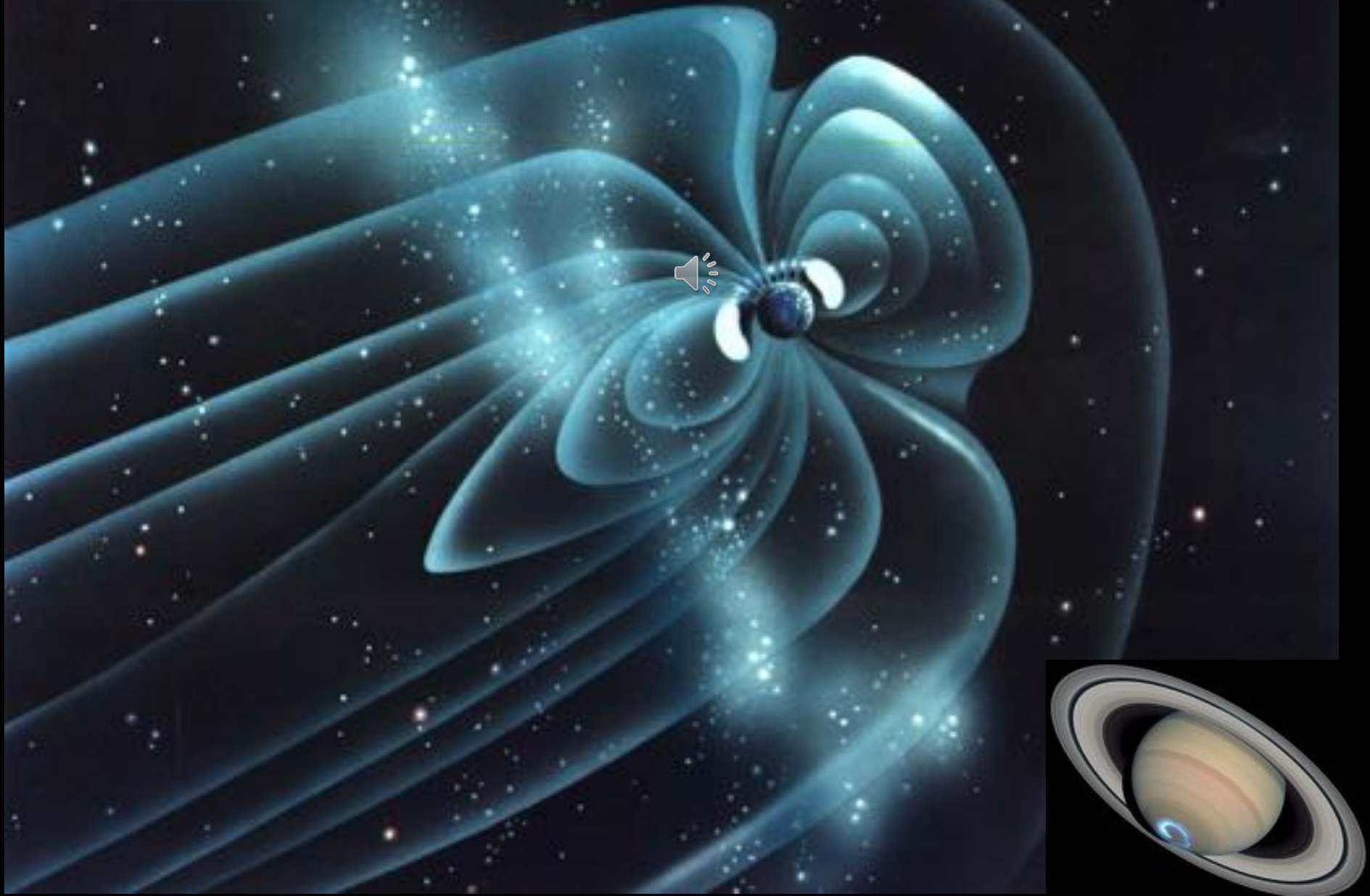


# Whistlers – The Plasmasphere

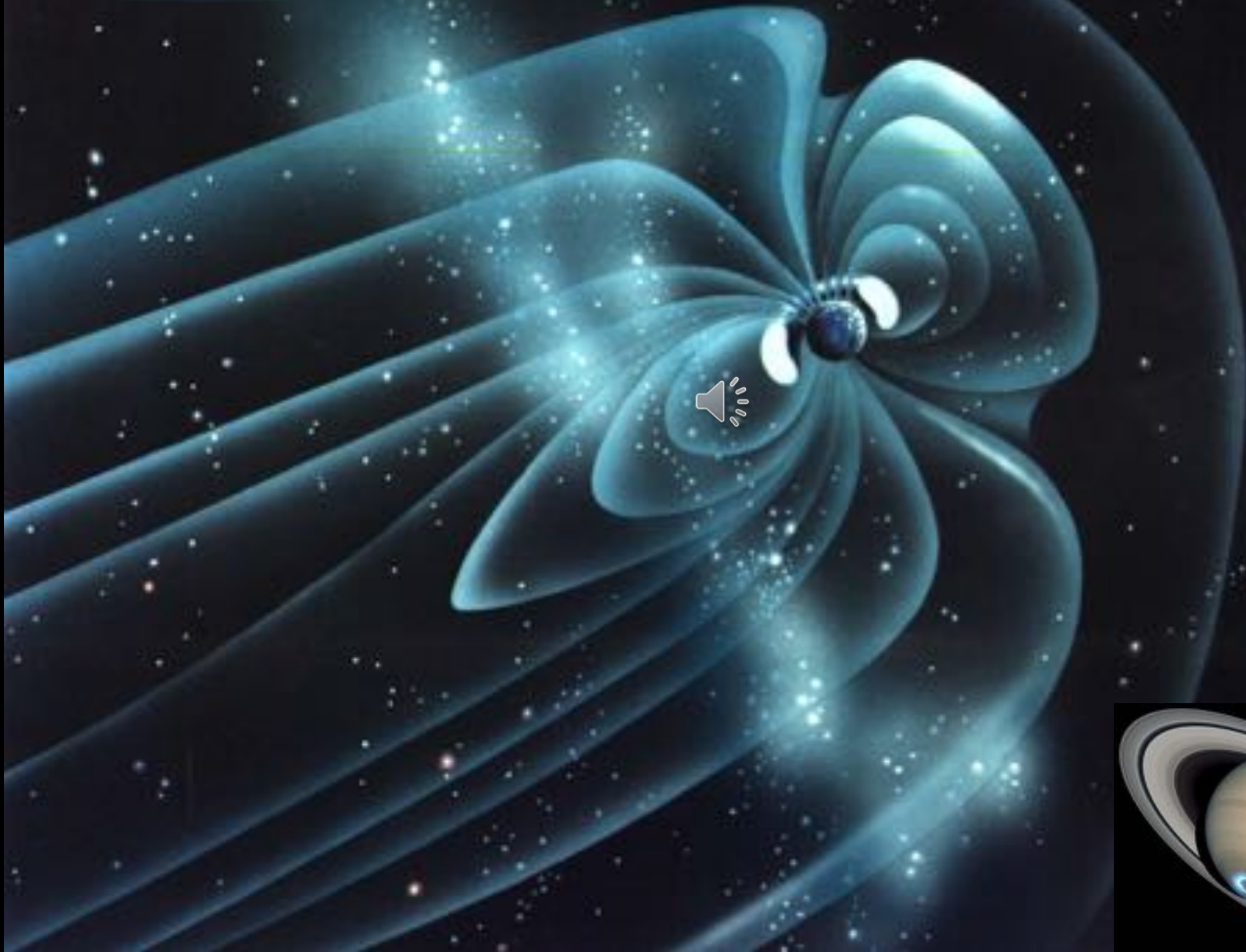




# Auroral Kilometric Radiation

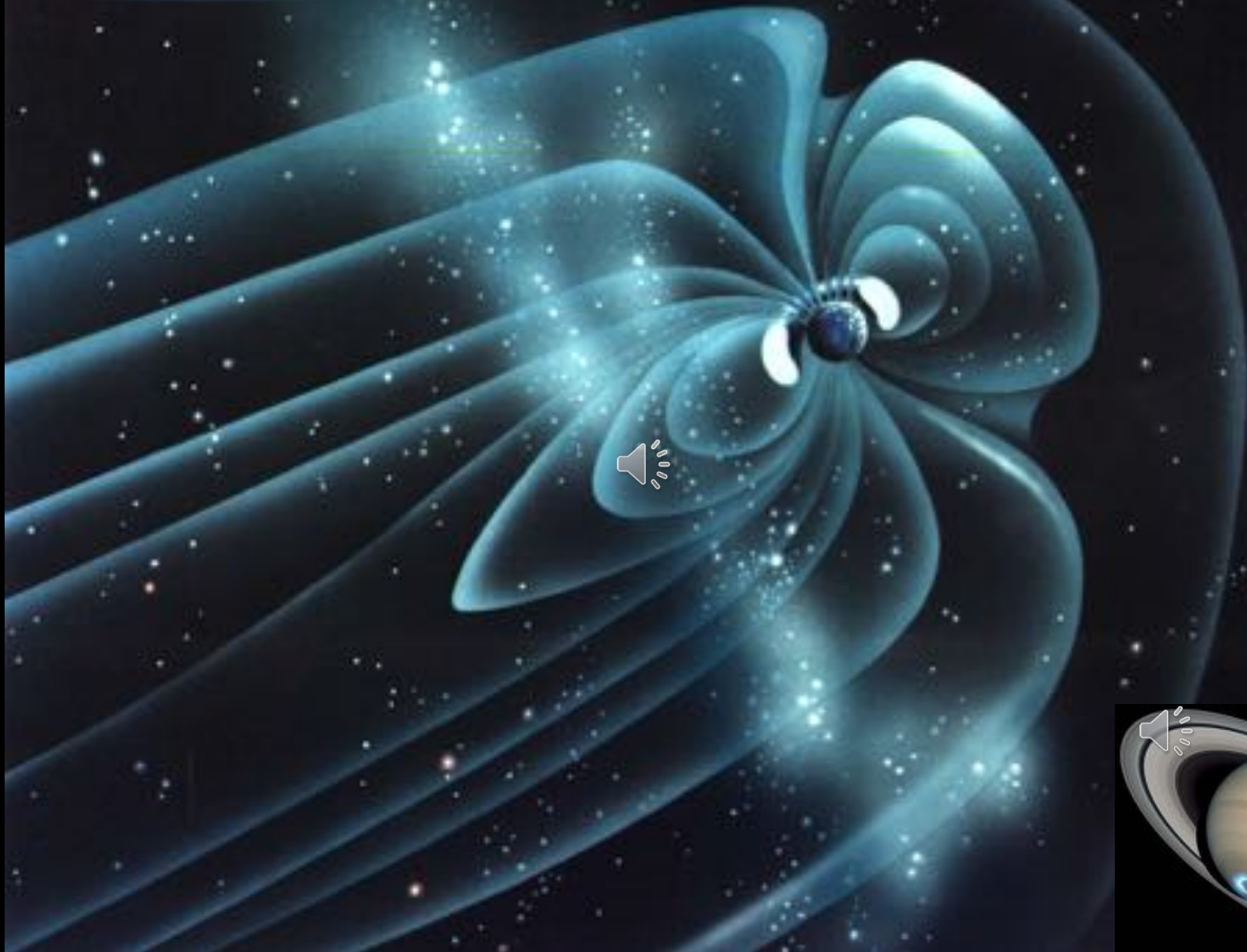


# Plasmaspheric Hiss



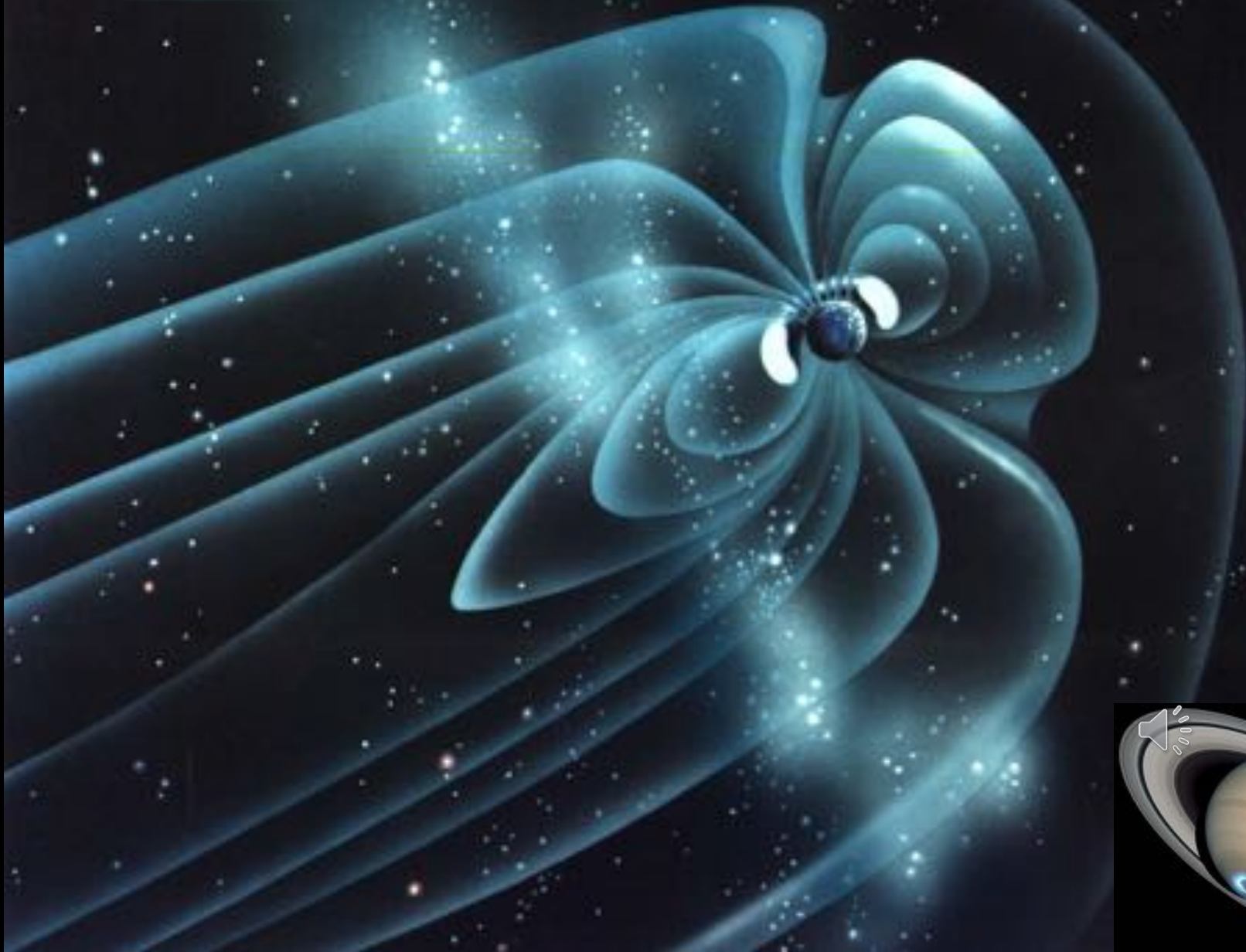


# Magnetospheric Chorus





# Voyager 1 – Saturn's Ring Plane



# Are We There Yet?

